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Eitschberger

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(54) **ELECTRICAL CONNECTOR**

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See application file for complete search history.

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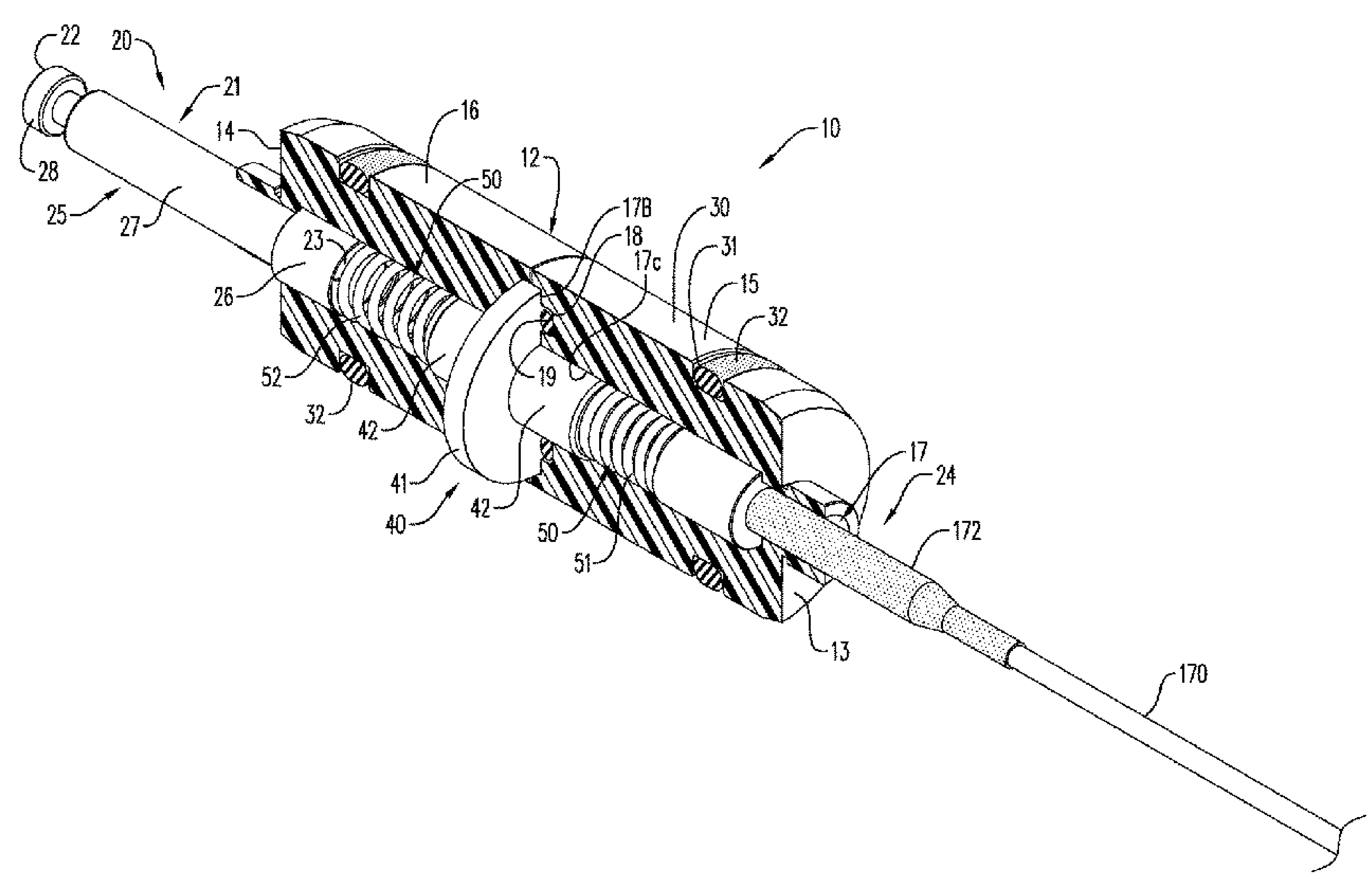
(57) **ABSTRACT**

An electrical connector may include a connector body extending along a longitudinal axis, a first electrical contact provided at a first end of the connector body, a first aperture provided in the first end of the connector body, a bore provided in an interior of the connector body and connected to the first aperture, and a conductive fixed body provided within the bore. The conductive fixed body may include a first contact surface on a first side of the conductive fixed body facing the first electrical contact along the longitudinal axis. A first spring may be provided in the bore between the first contact surface and the first electrical contact, and the first spring may be in contact with the first contact surface and the first electrical contact.

20 Claims, 16 Drawing Sheets



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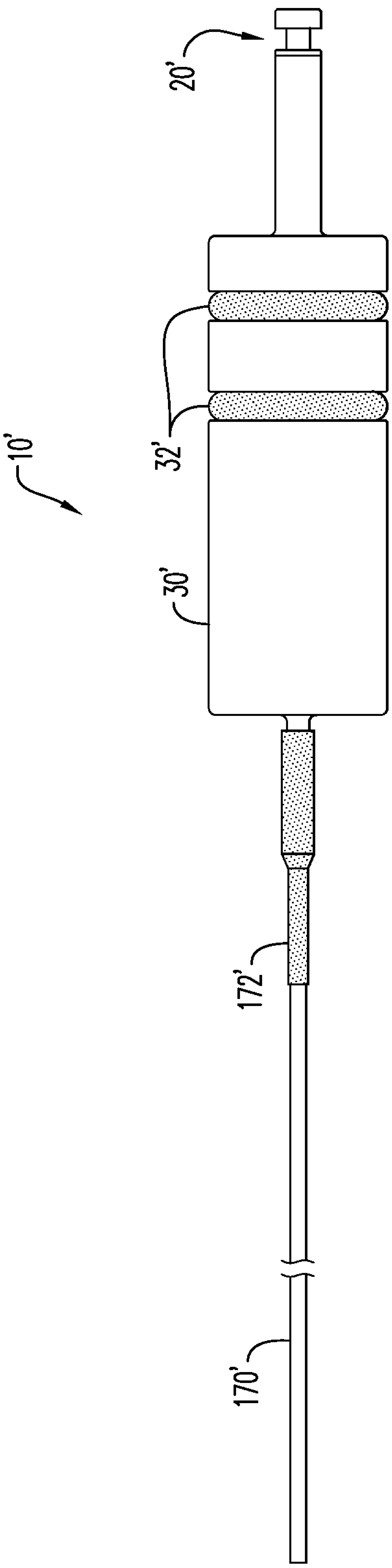

FIG. 1
(PRIOR ART)

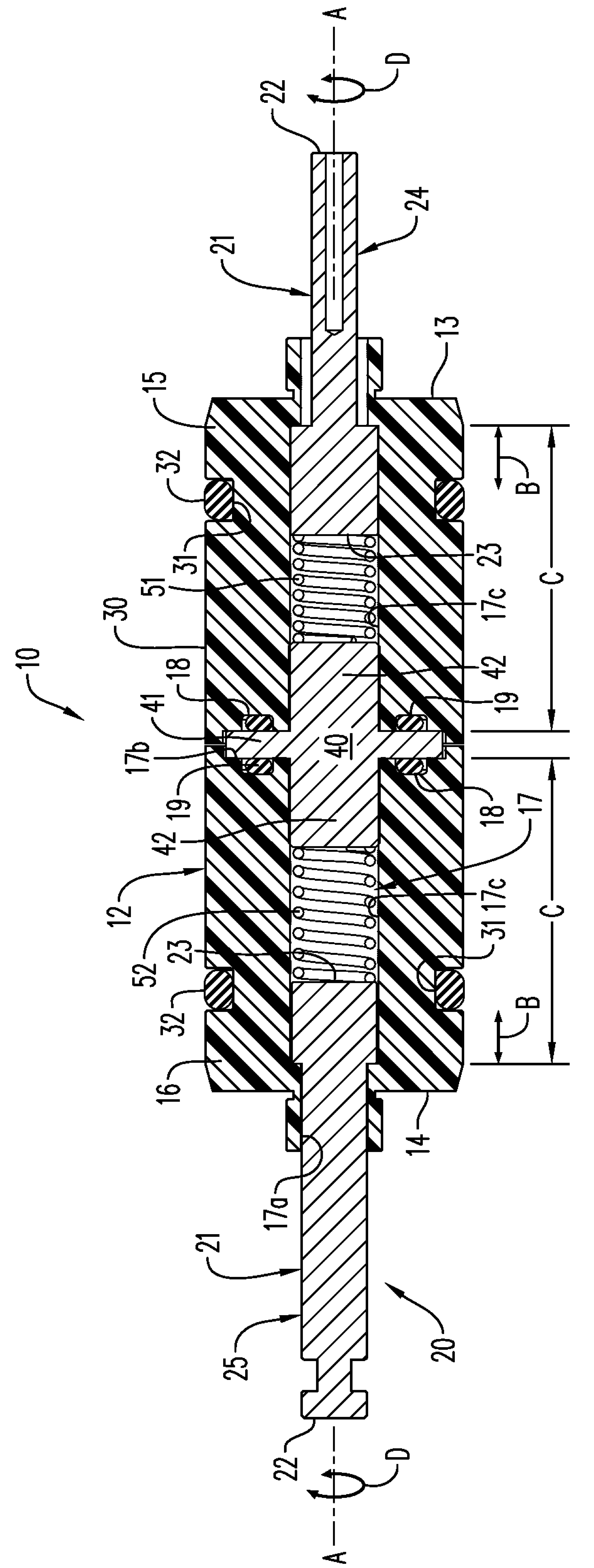
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FIG. 2

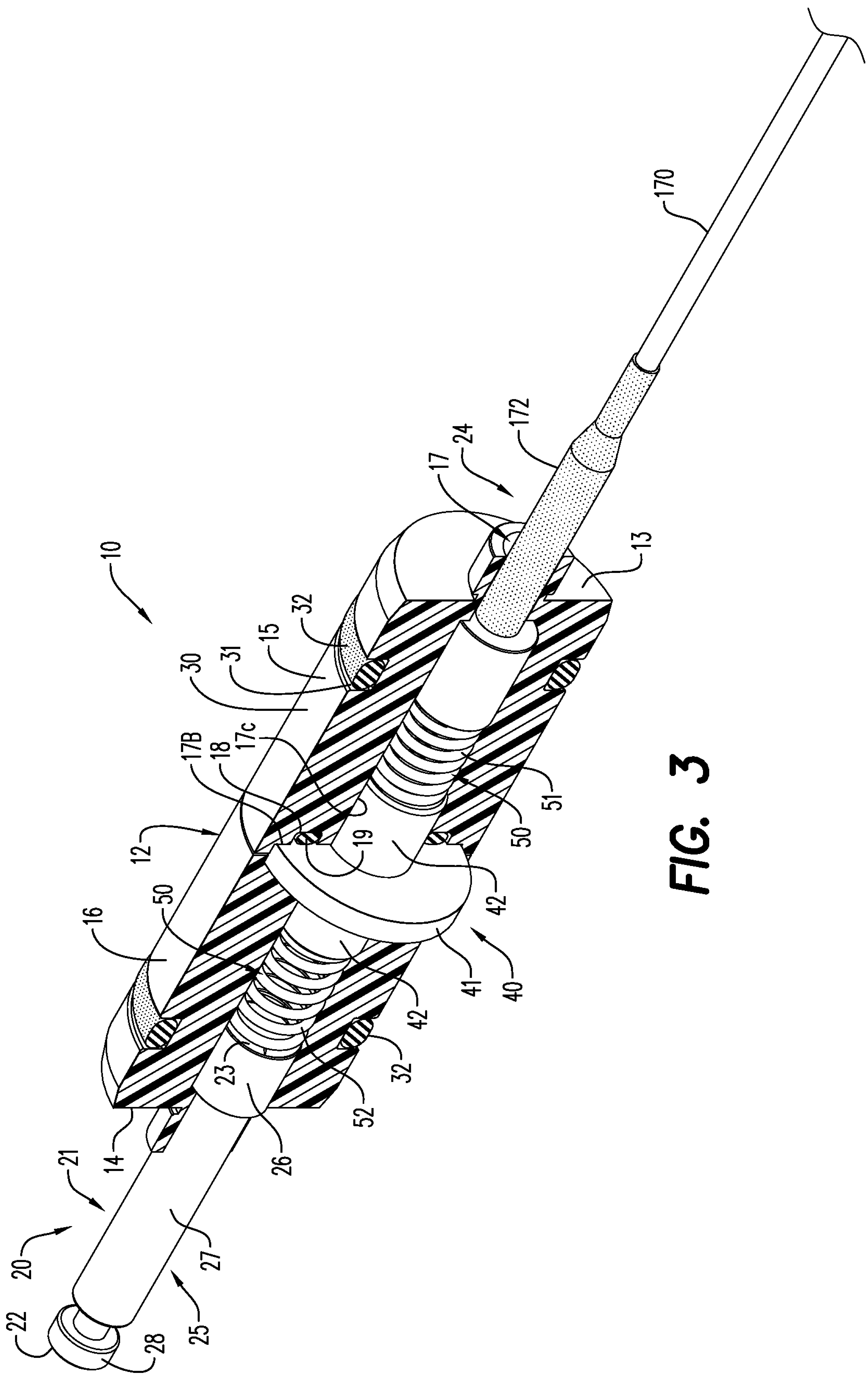
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FIG. 3

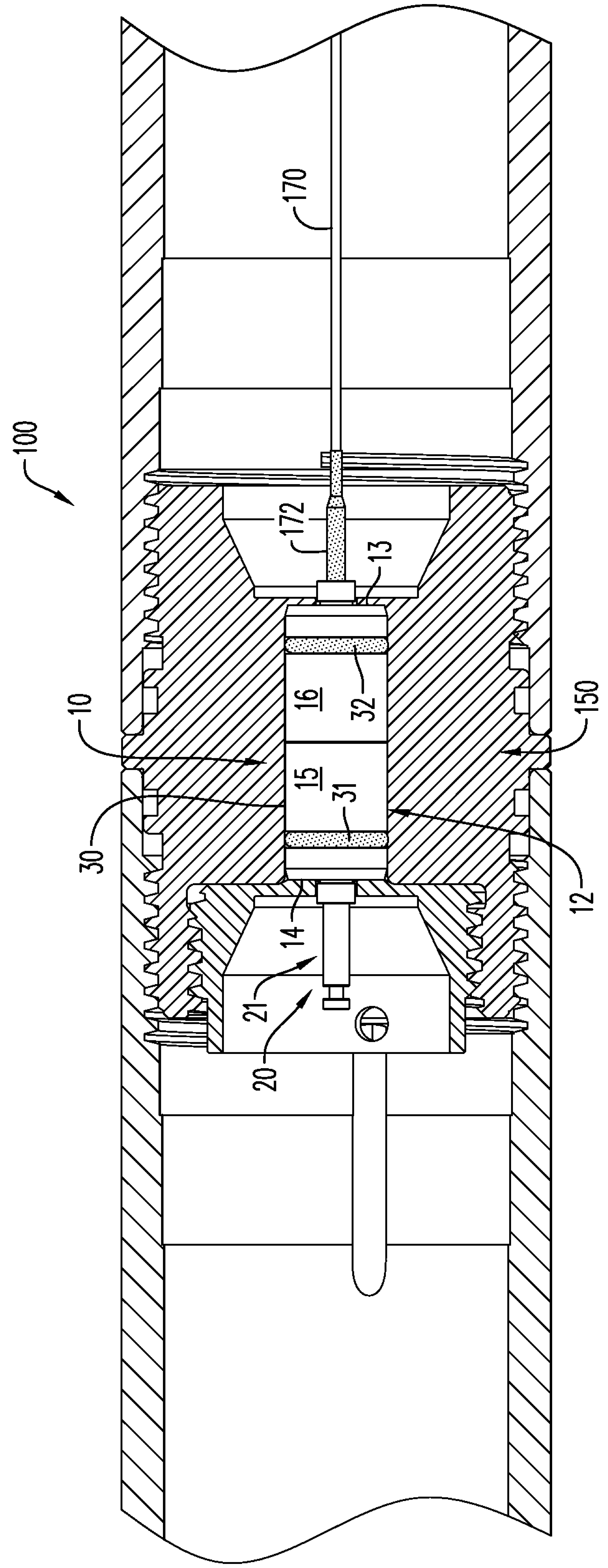

FIG. 4

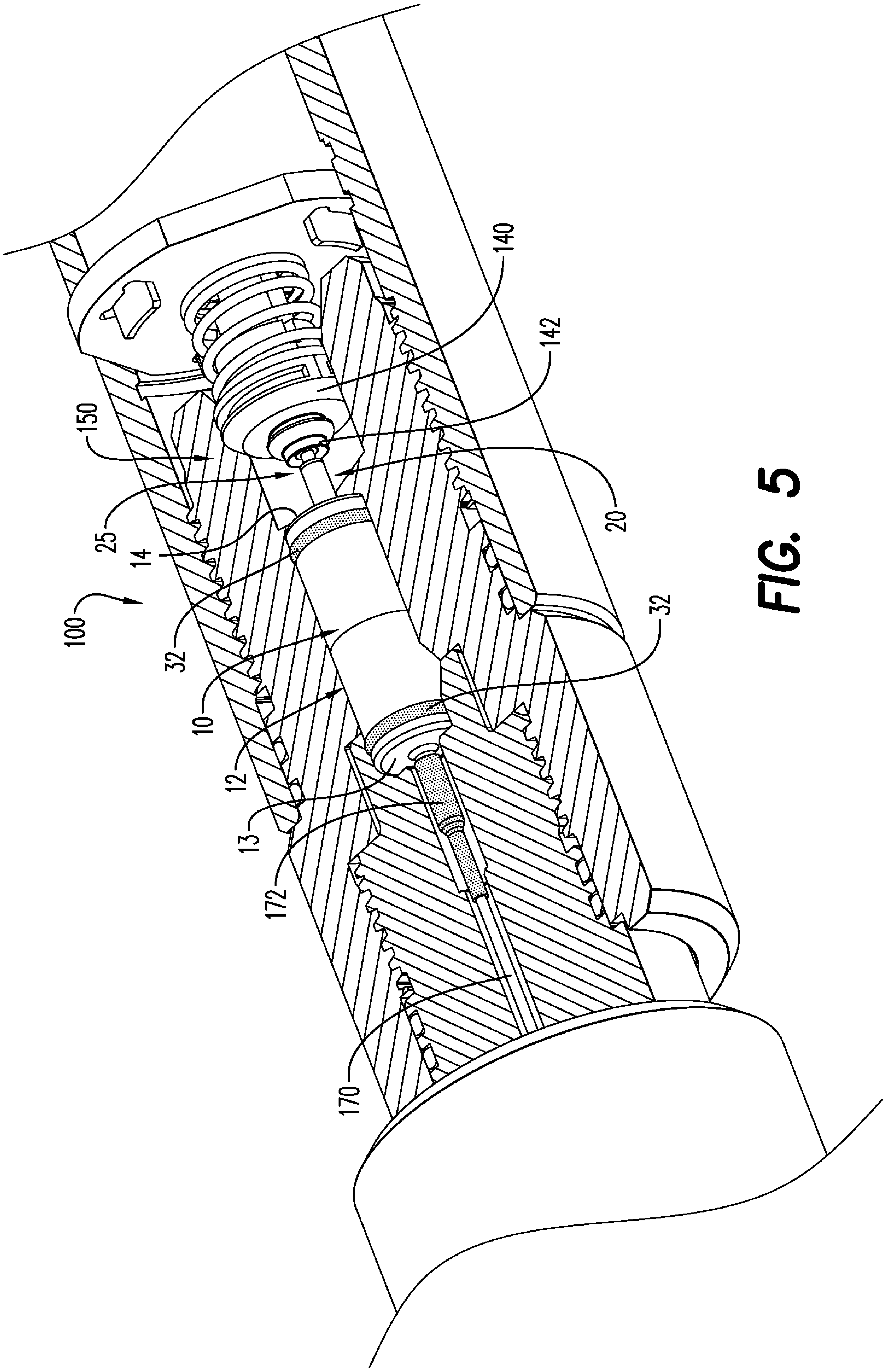

FIG. 5

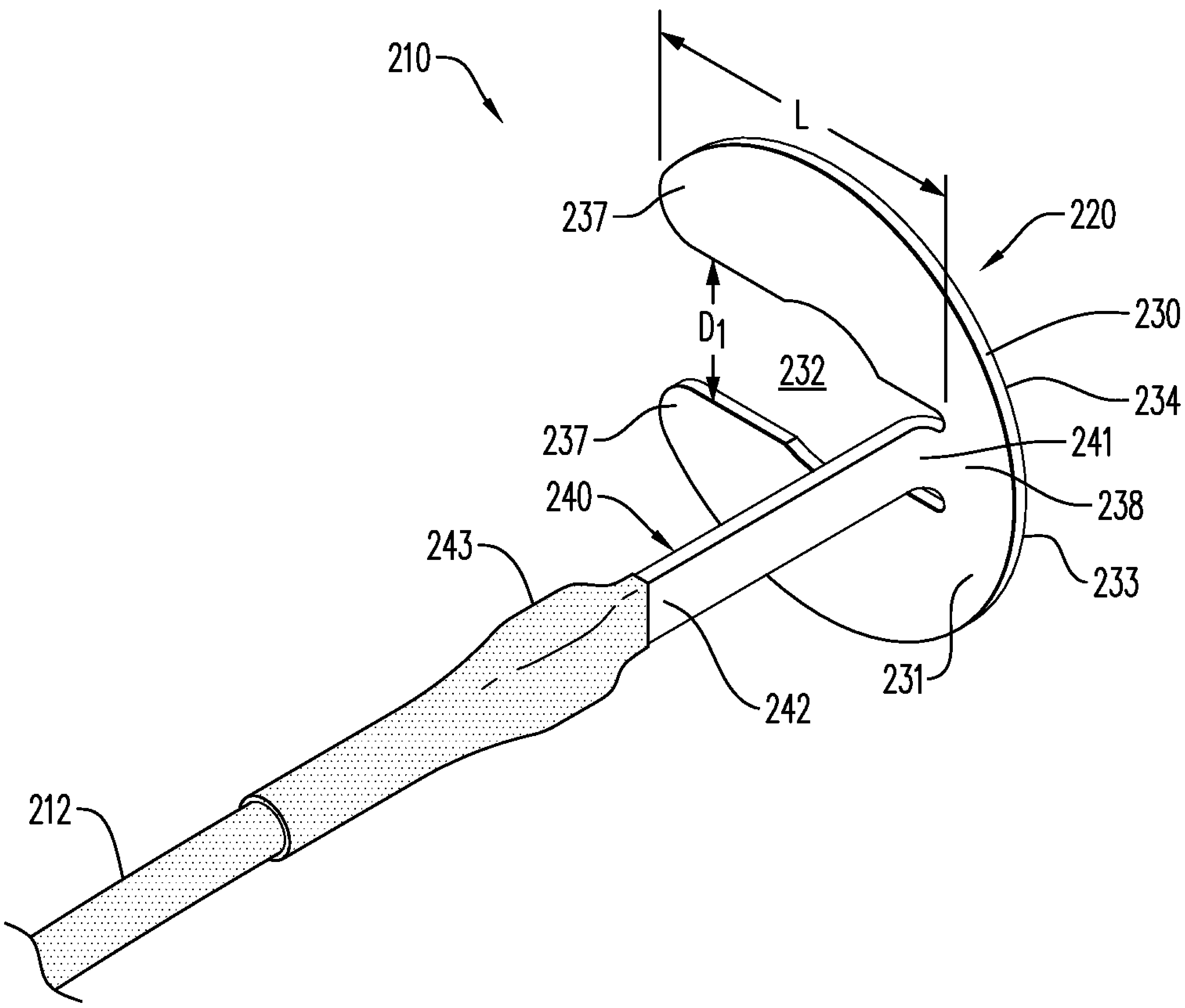

FIG. 6

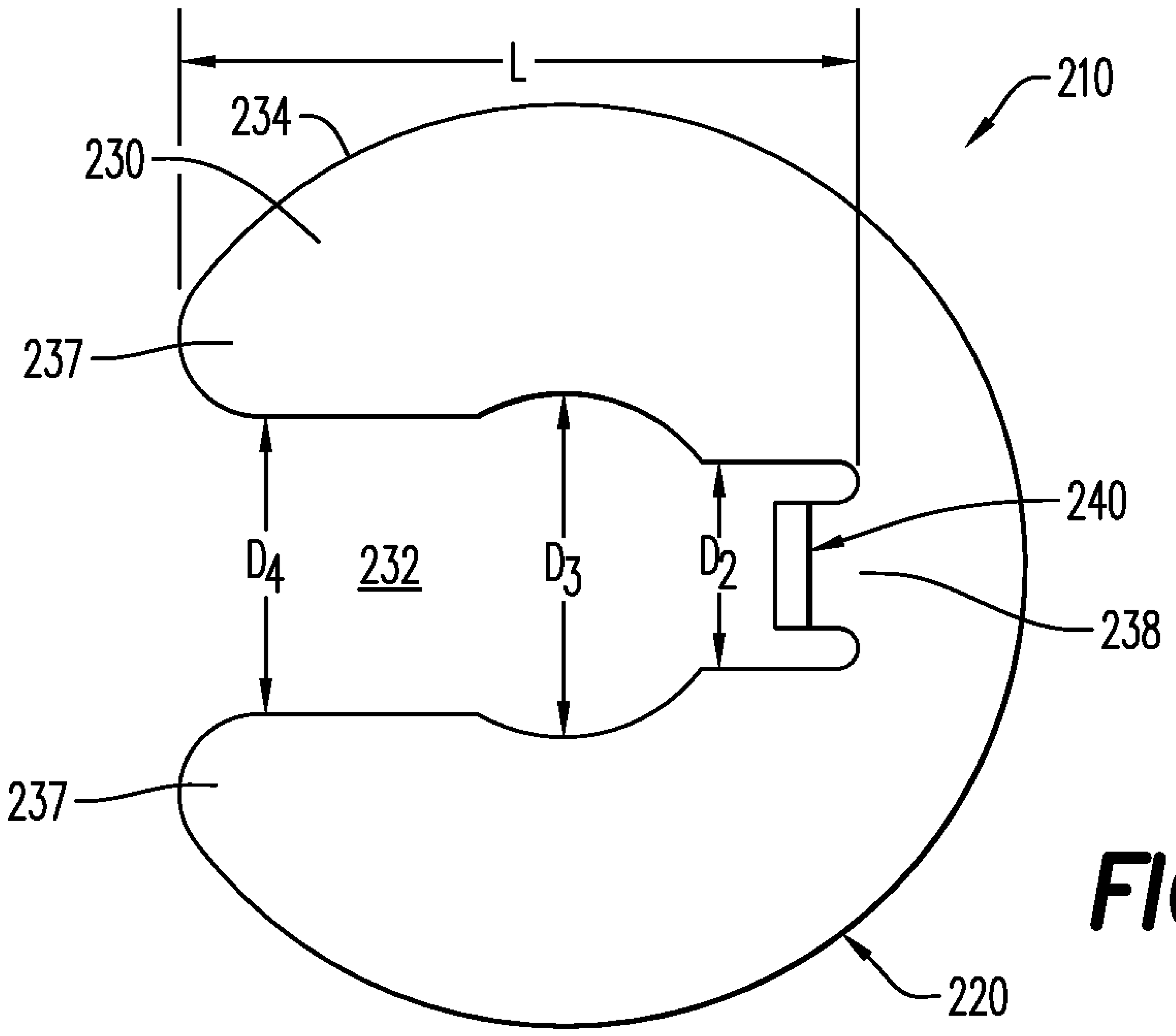
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FIG. 7

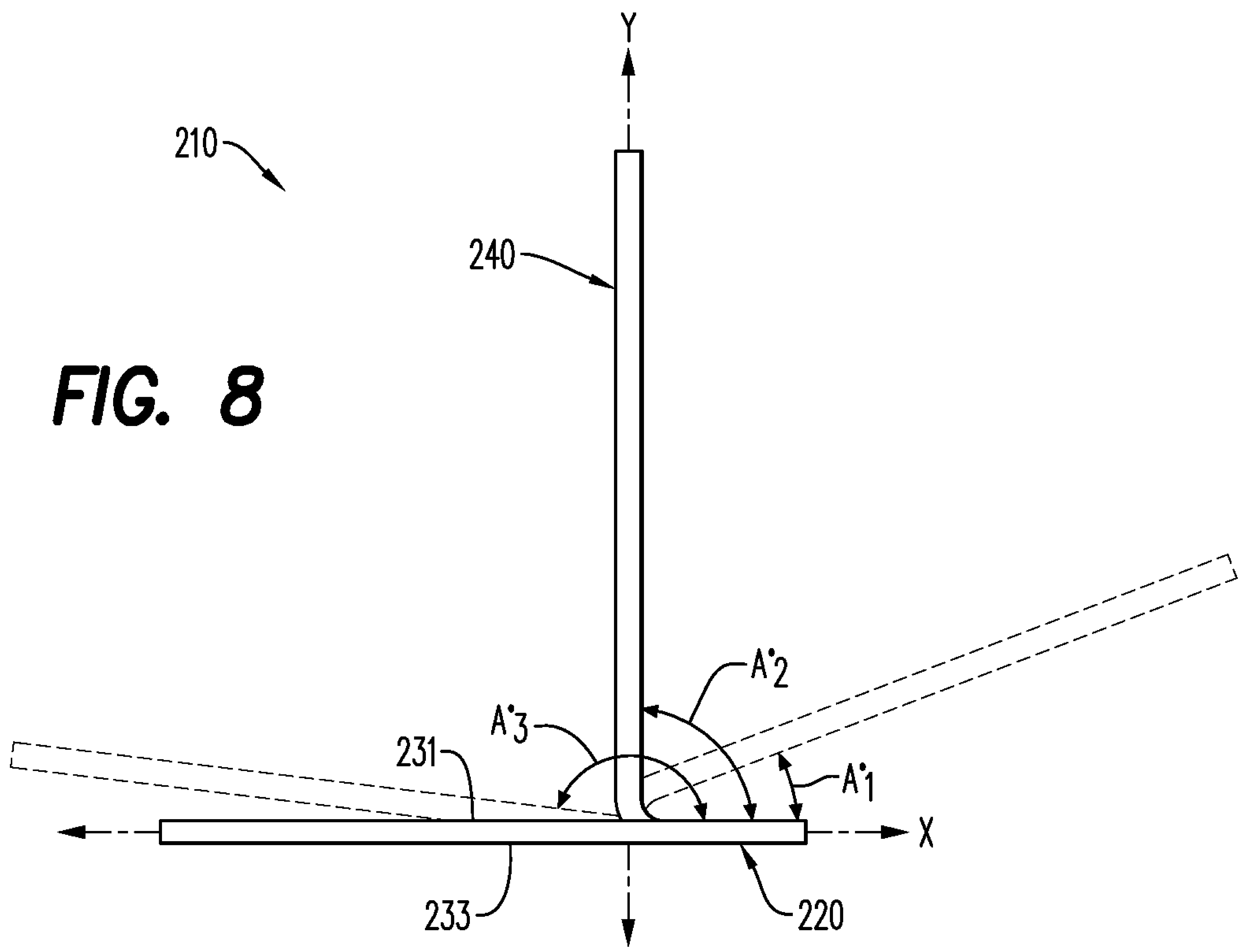
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FIG. 8

FIG. 9A

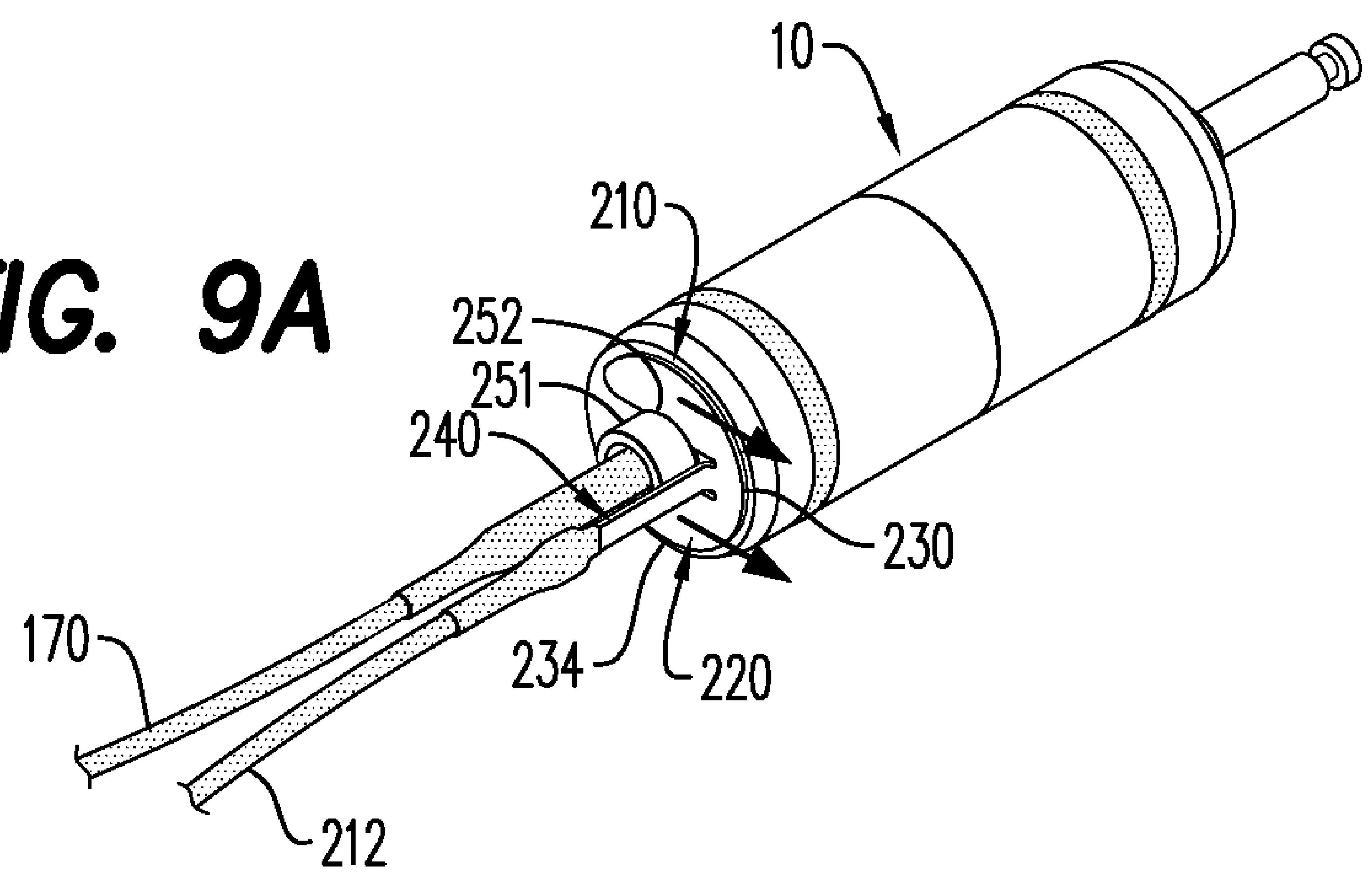


FIG. 9B

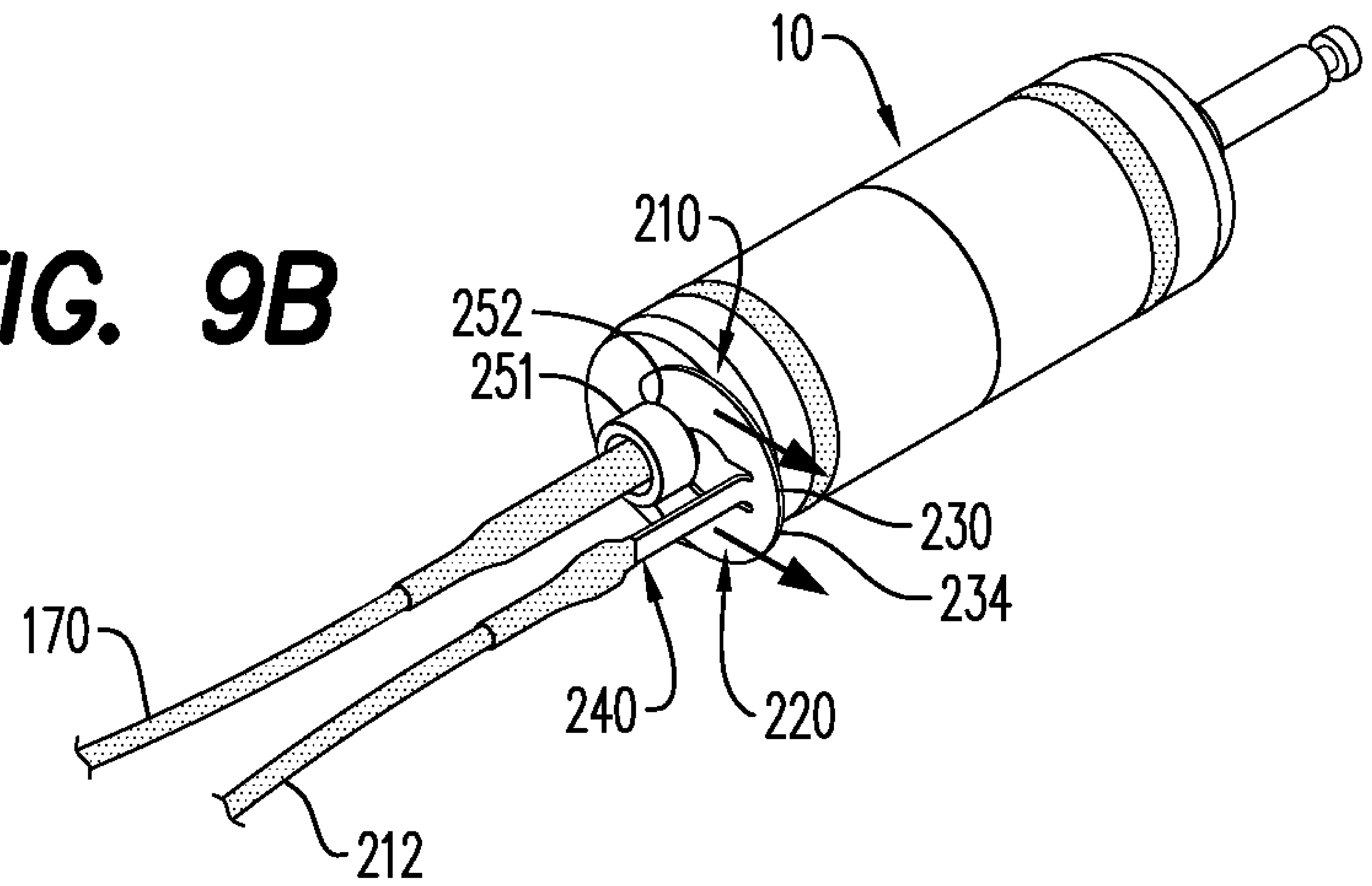
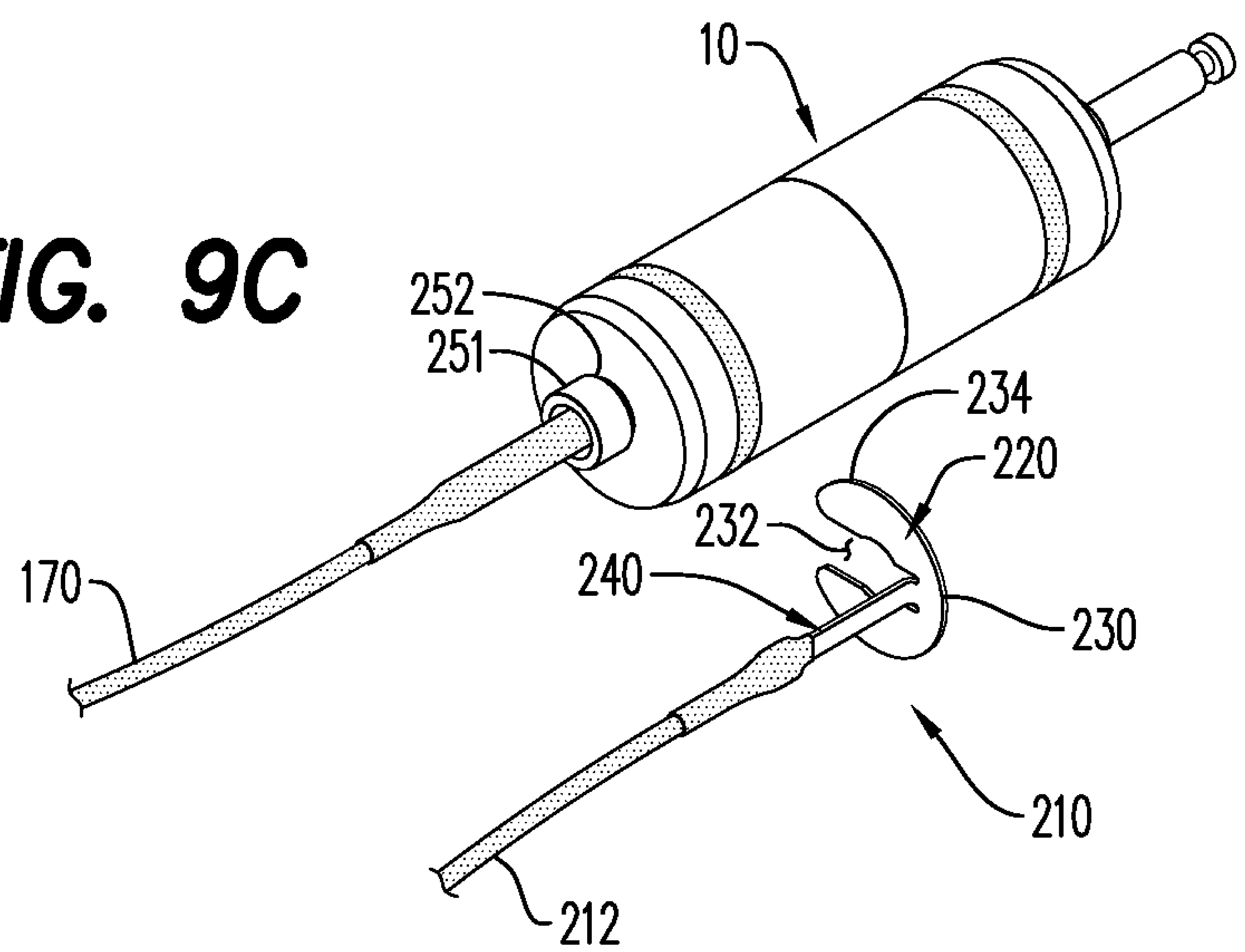


FIG. 9C



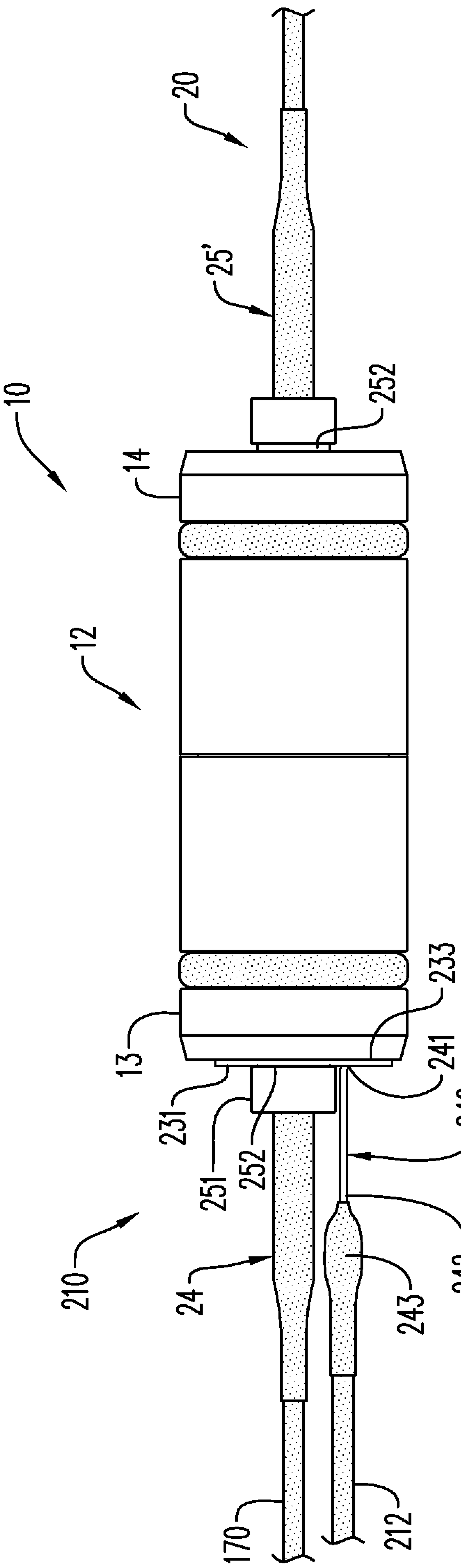

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FIG. 10

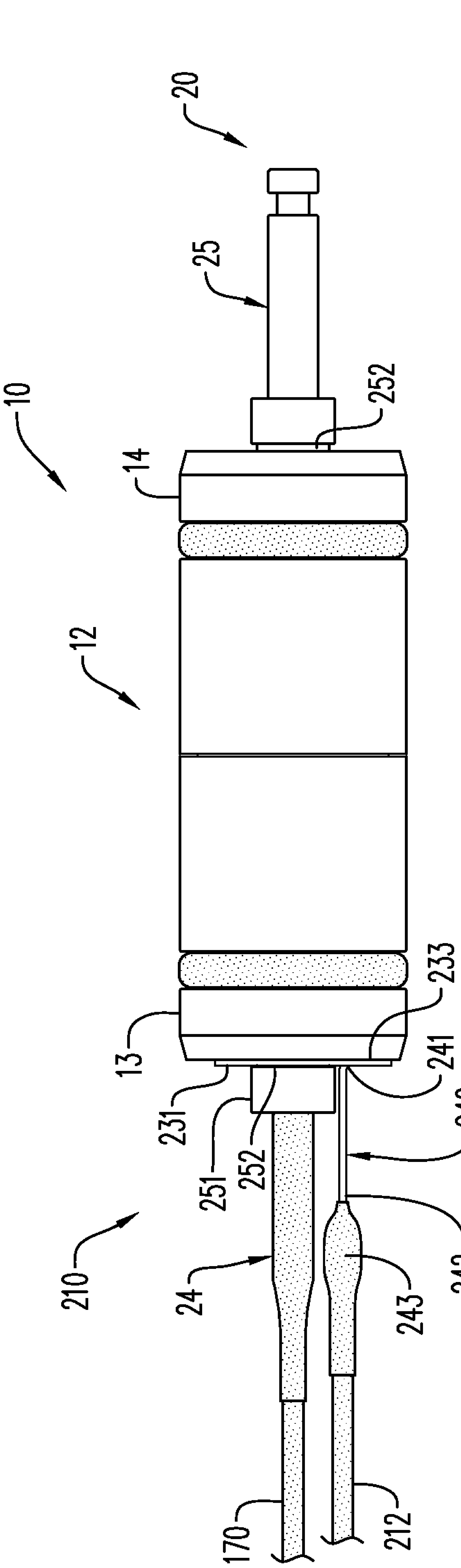
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FIG. 11

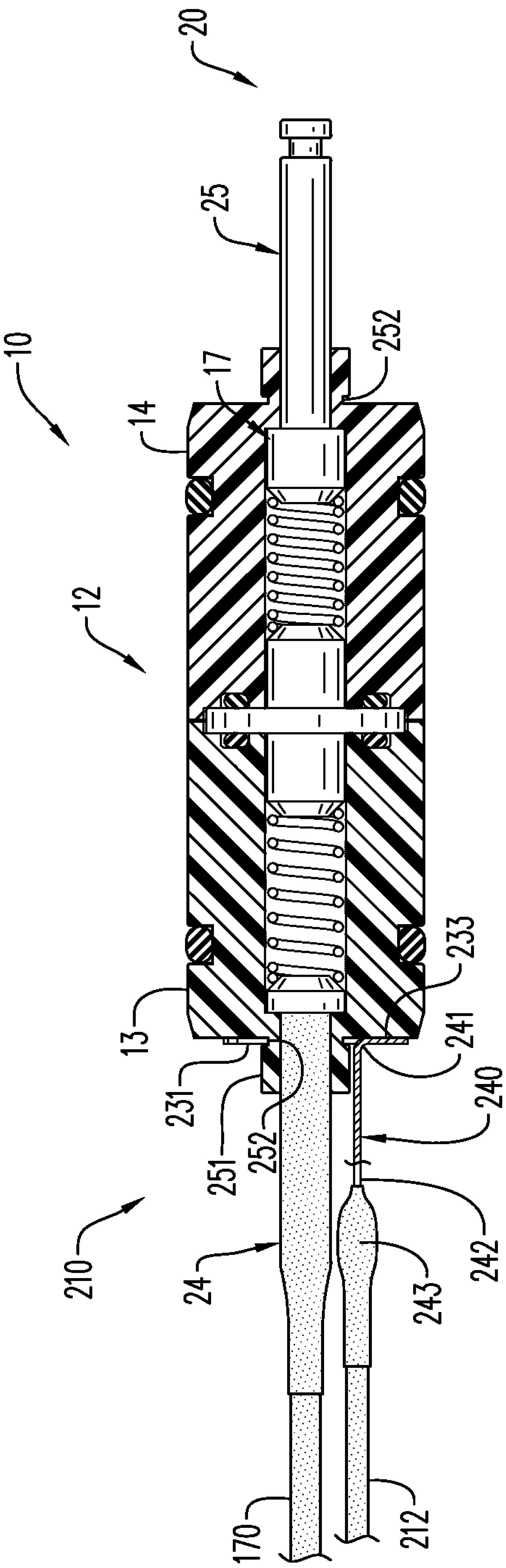
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FIG. 12

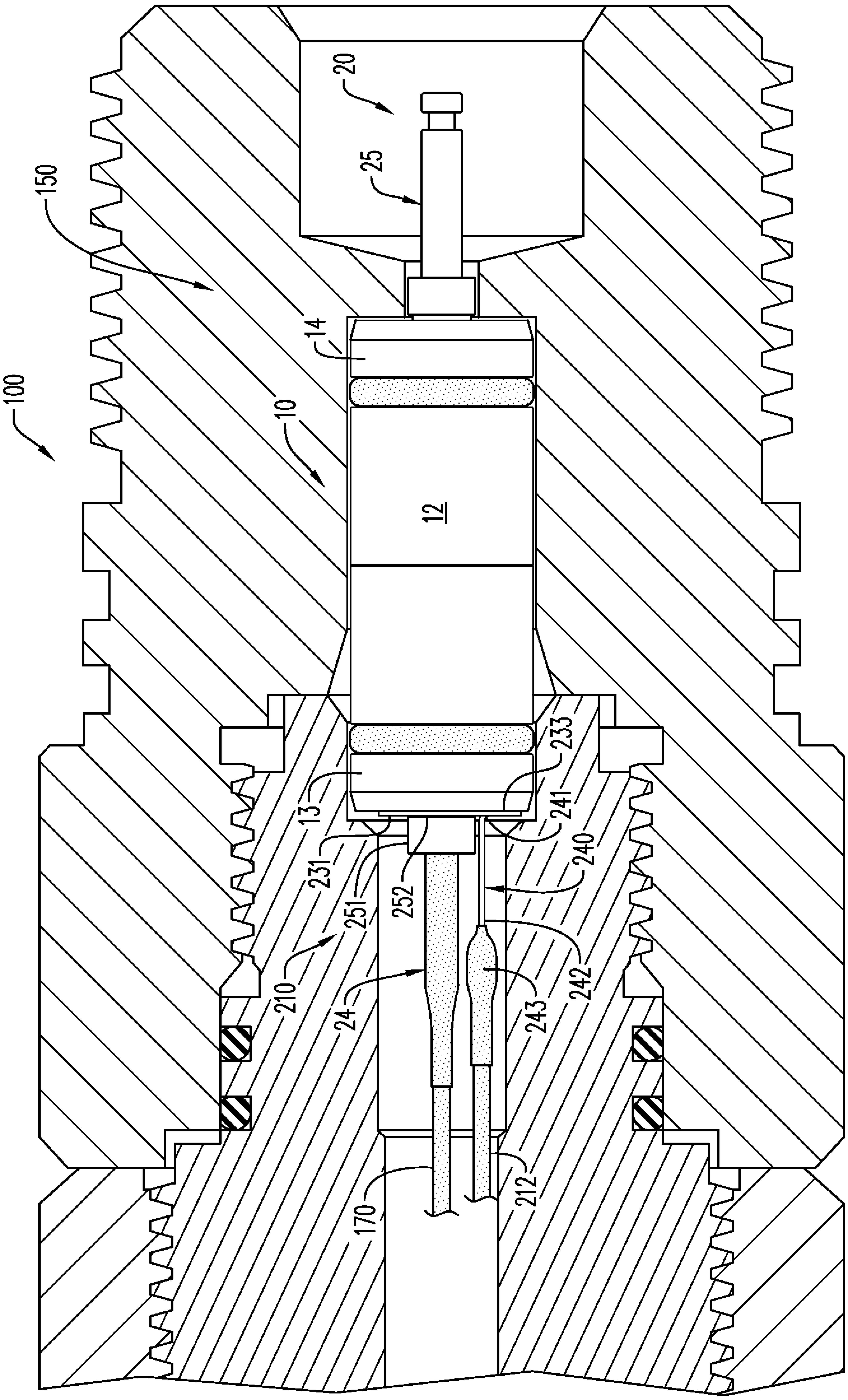
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FIG. 13

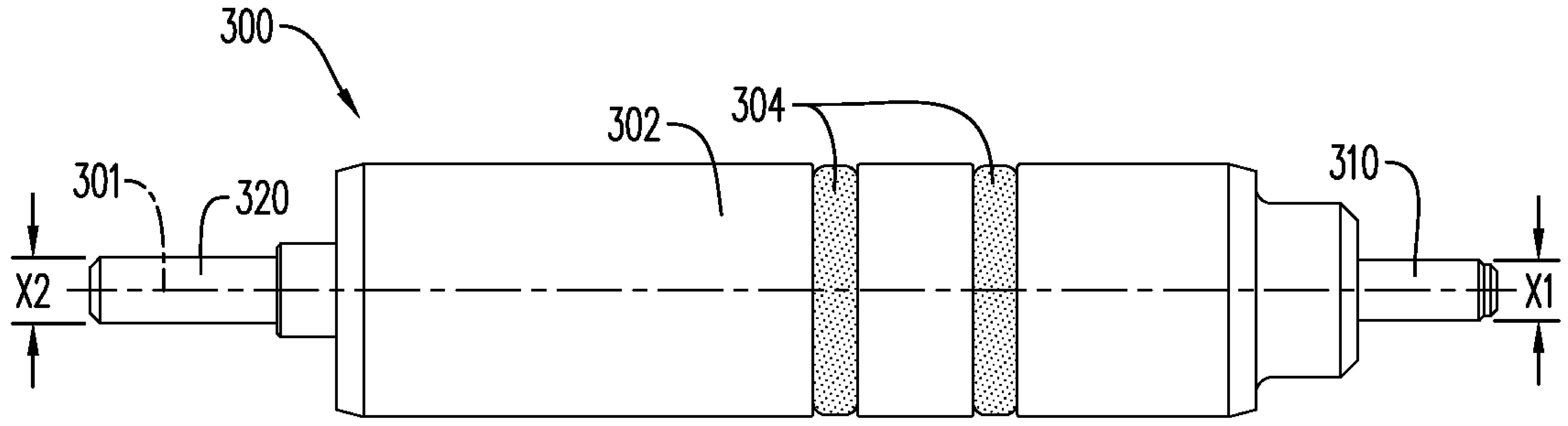

FIG. 14

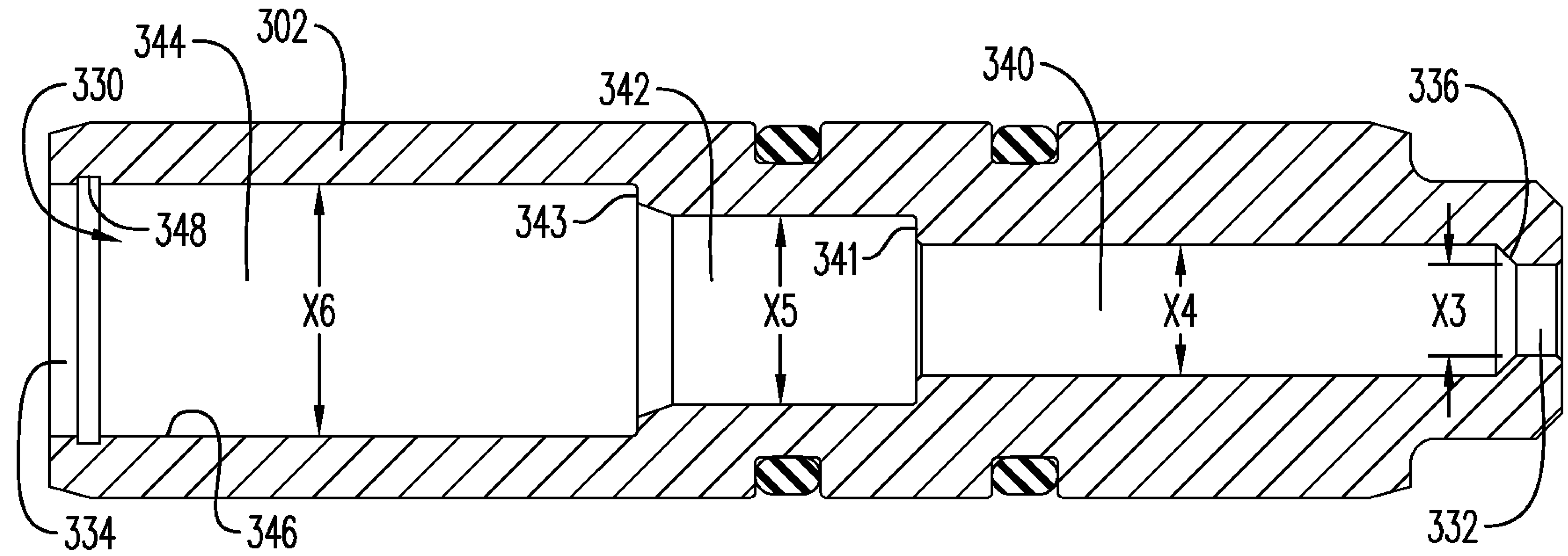

FIG. 15

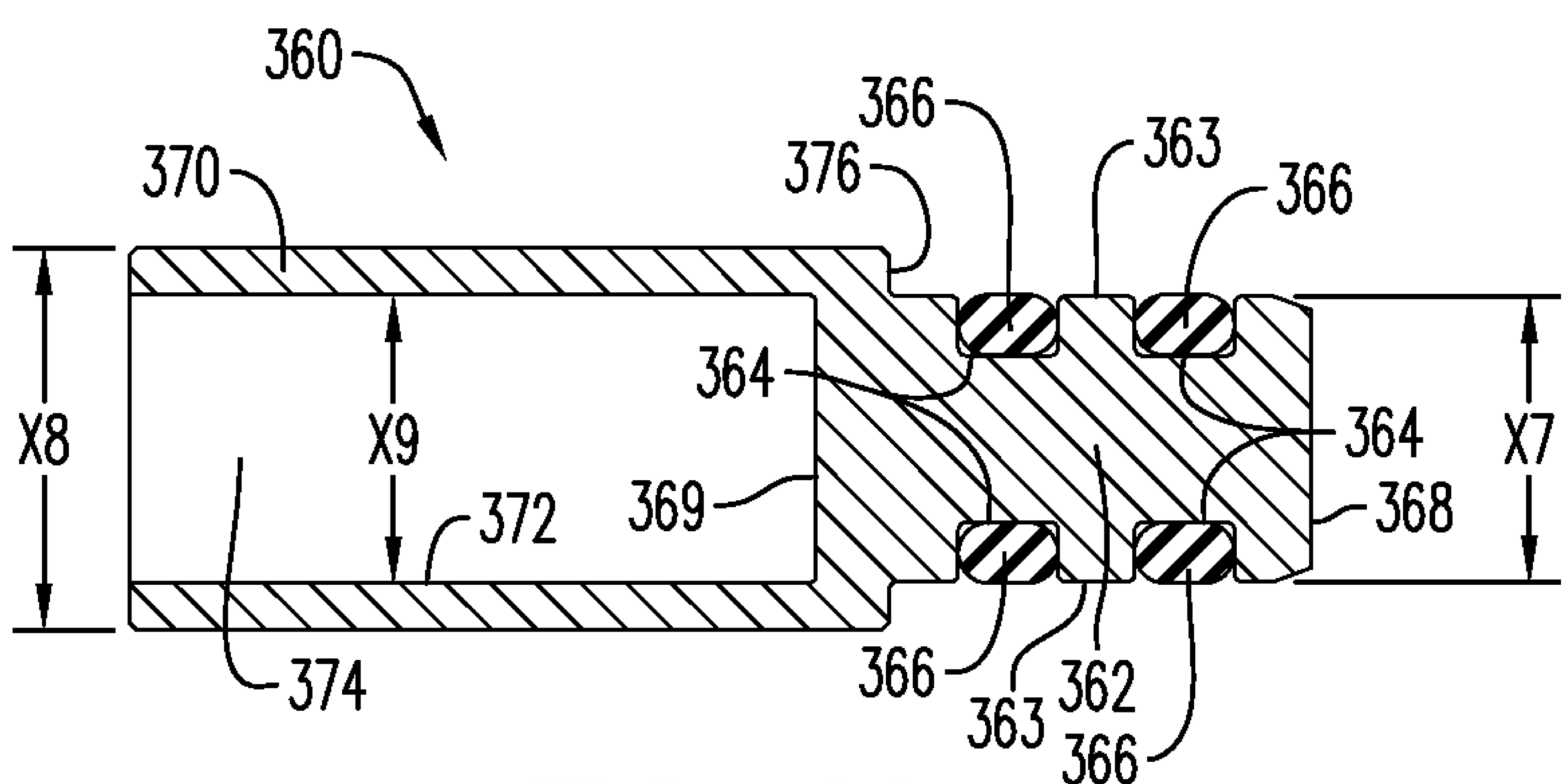

FIG. 16

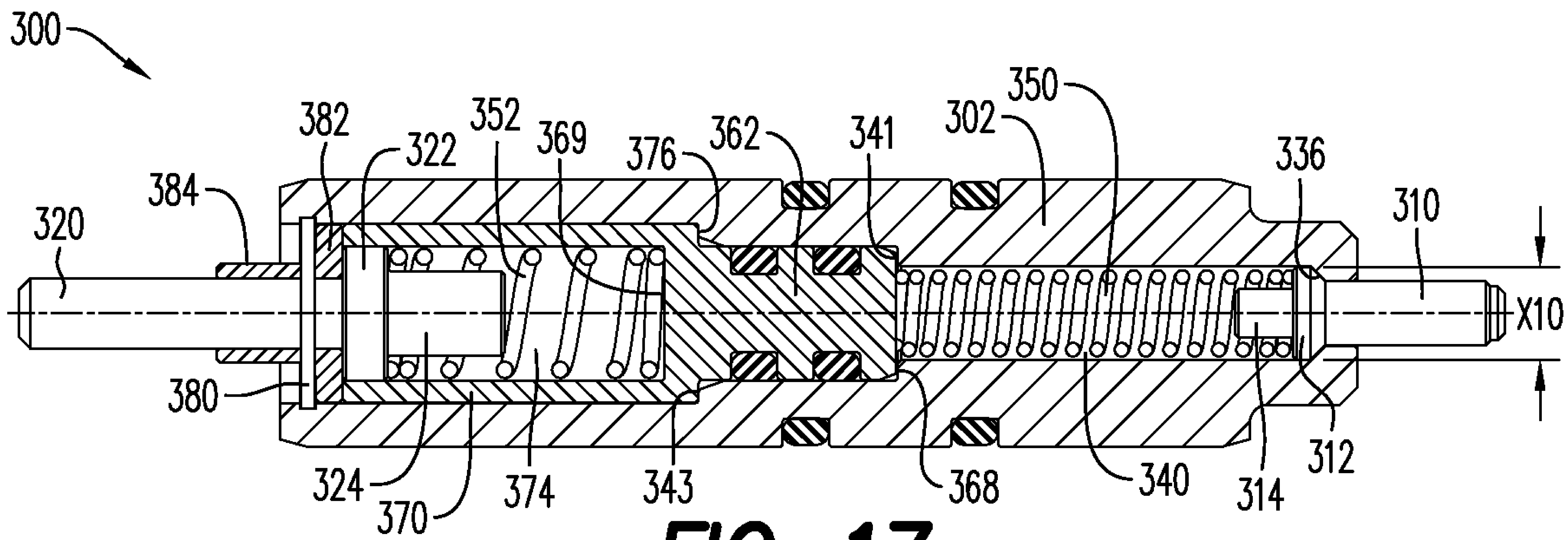

FIG. 17

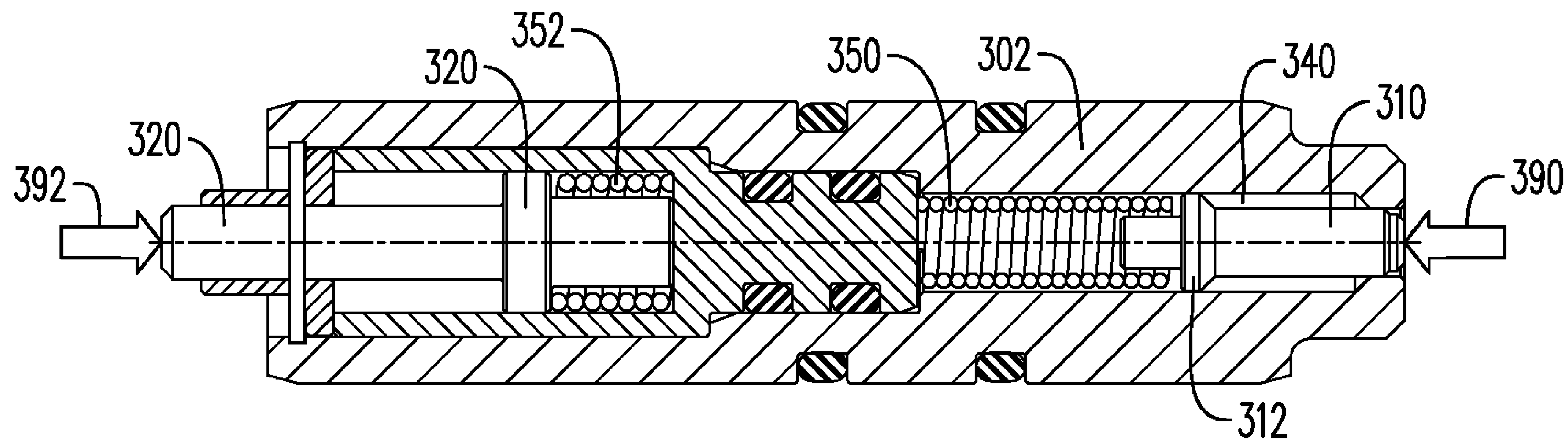

FIG. 18

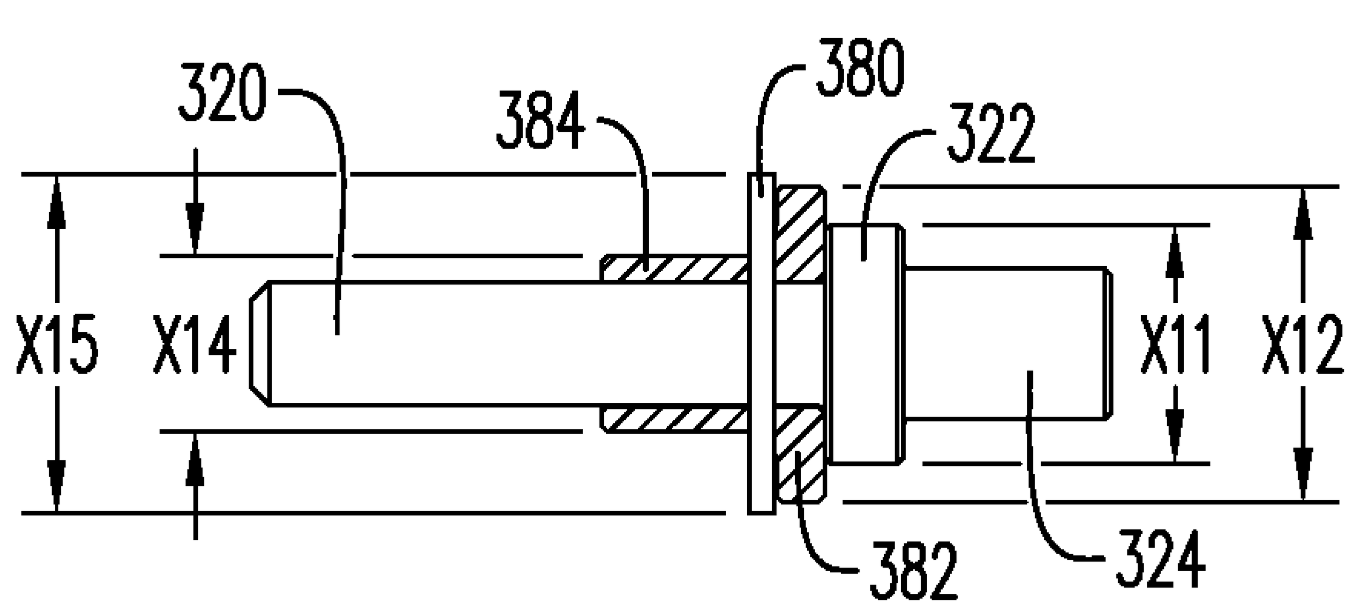

FIG. 19

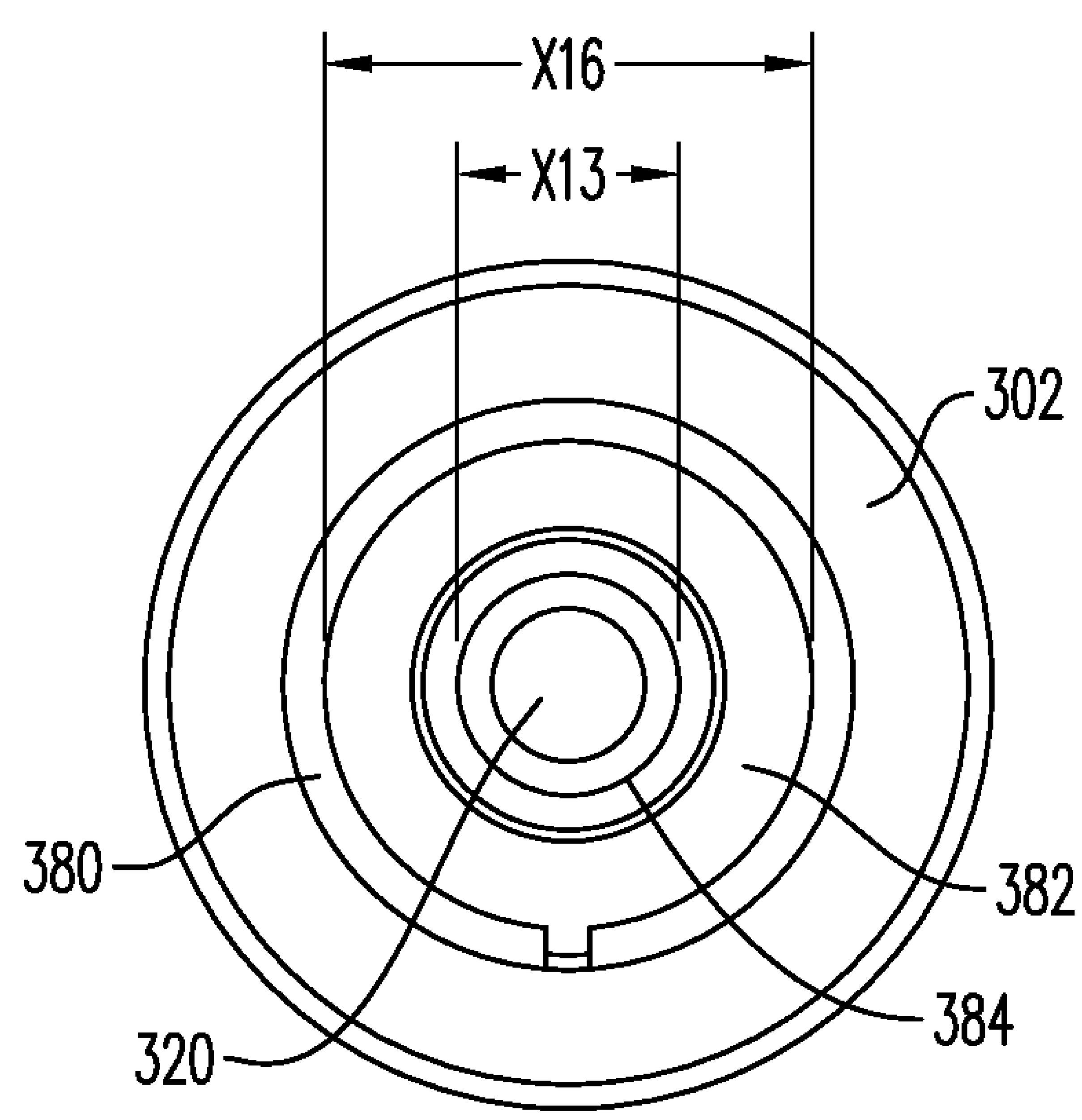

FIG. 20

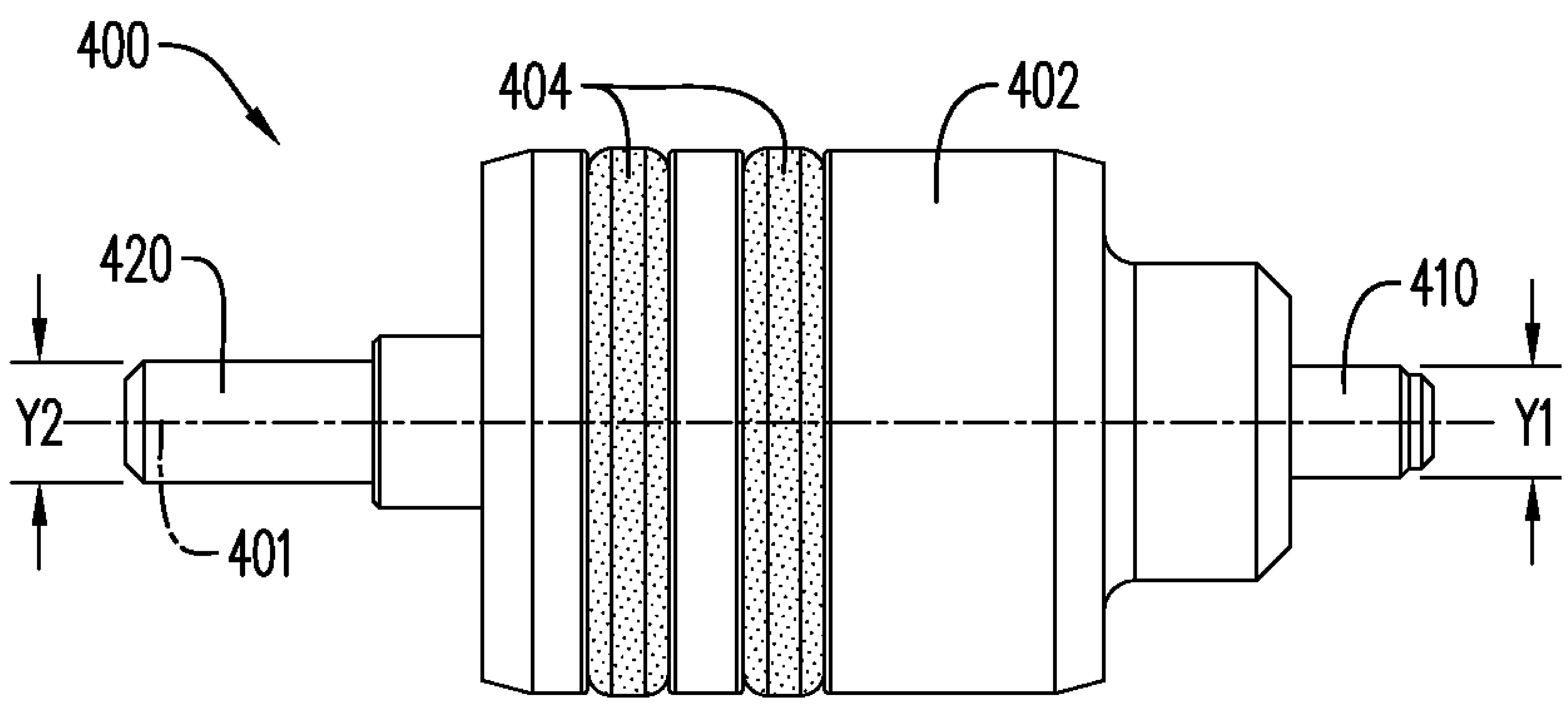

FIG. 21

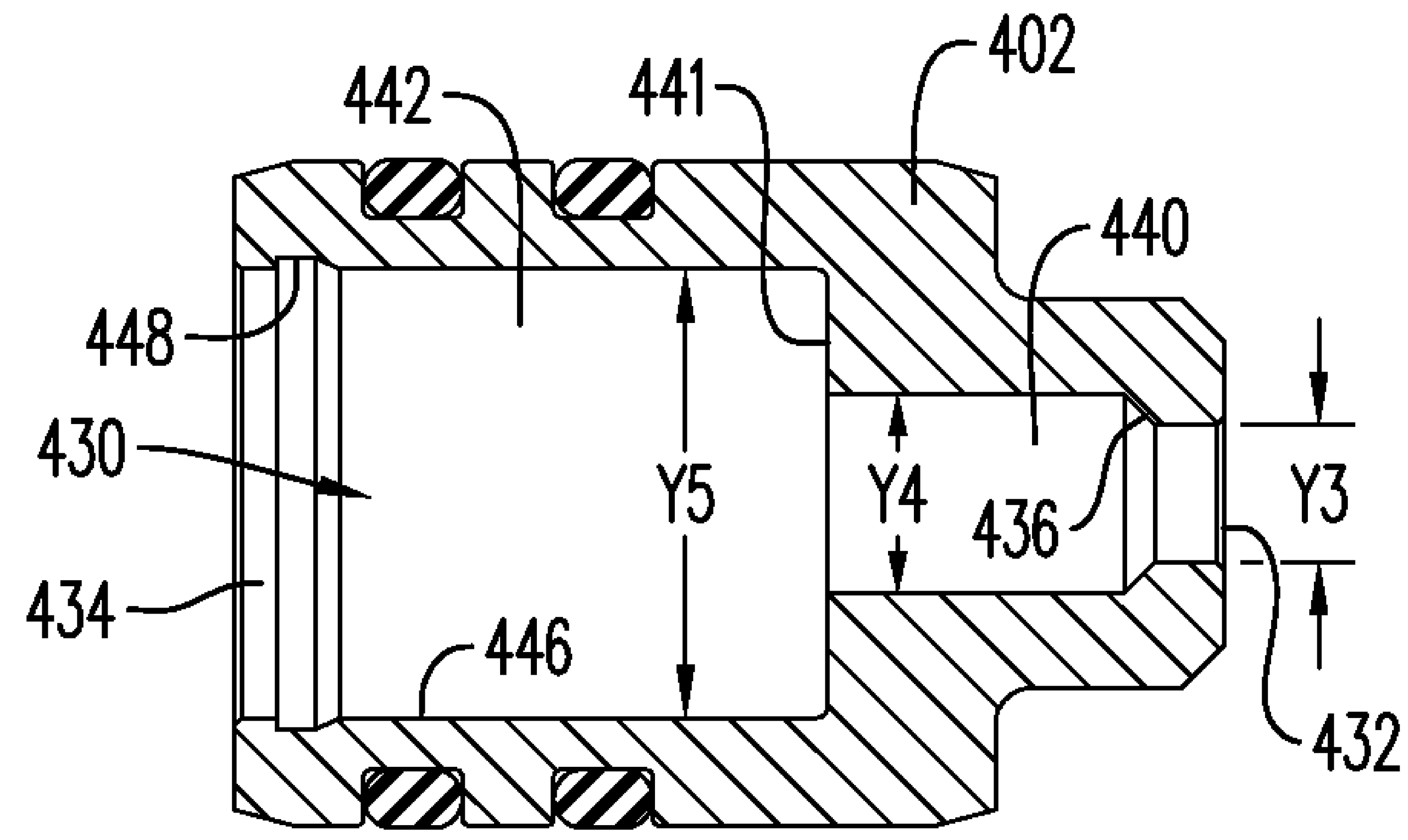

FIG. 22

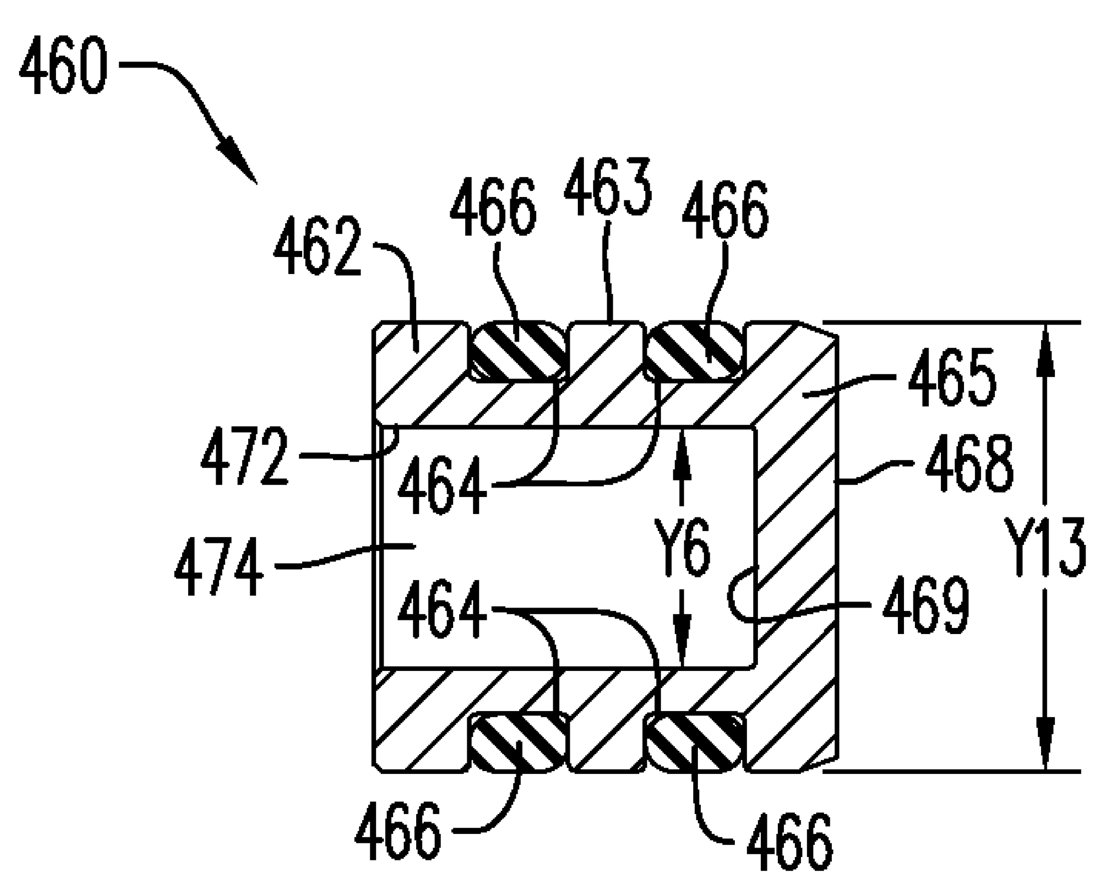

FIG. 23

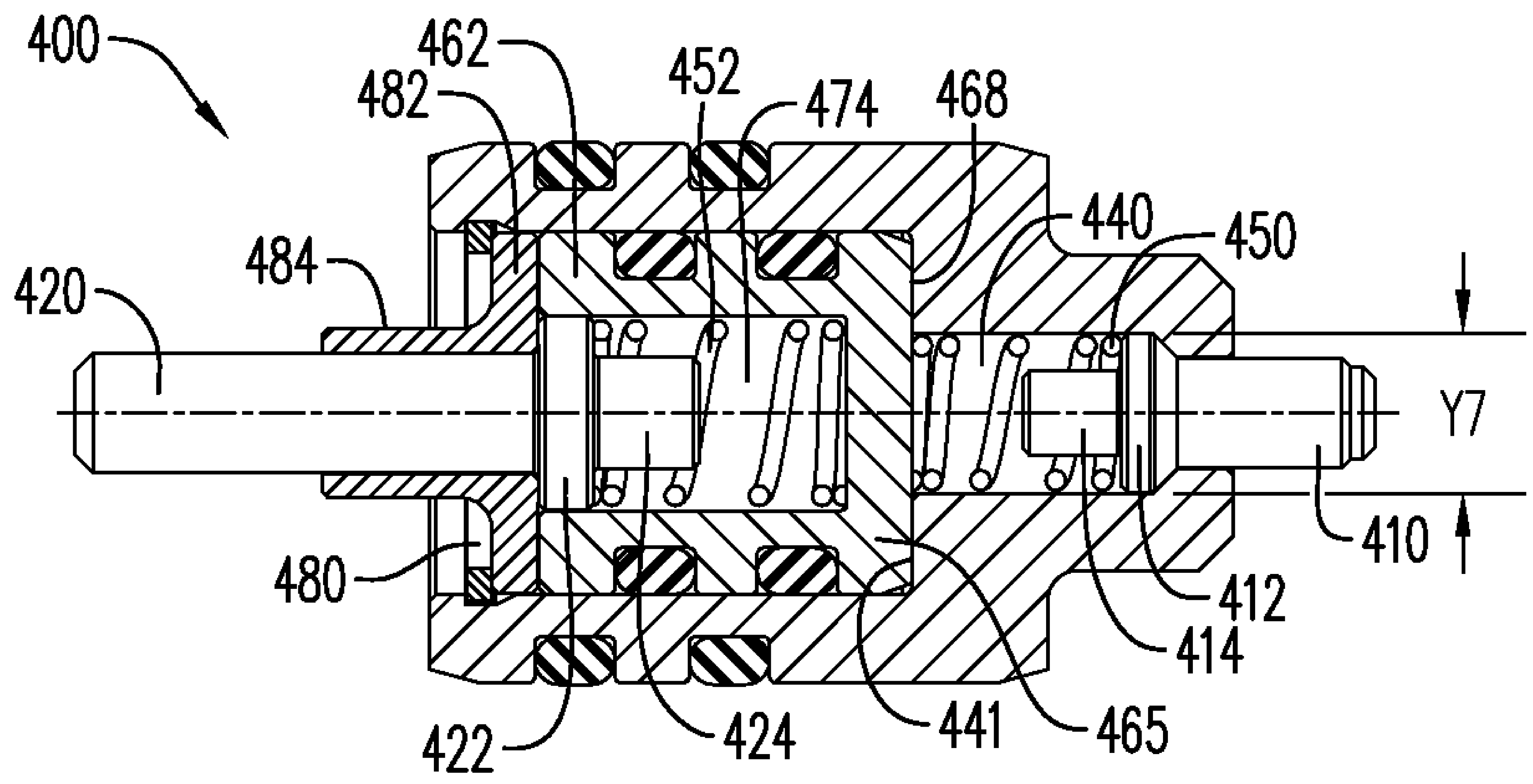

FIG. 24

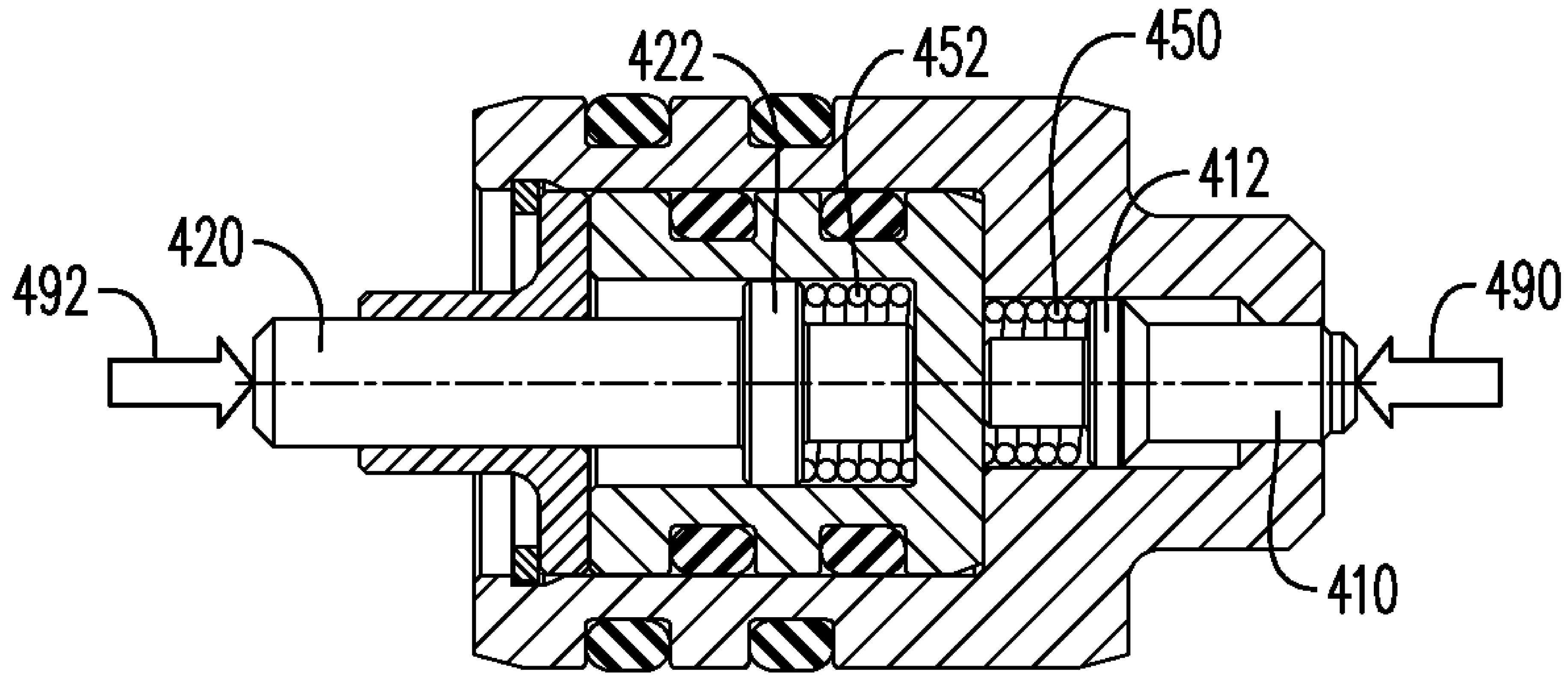

FIG. 25

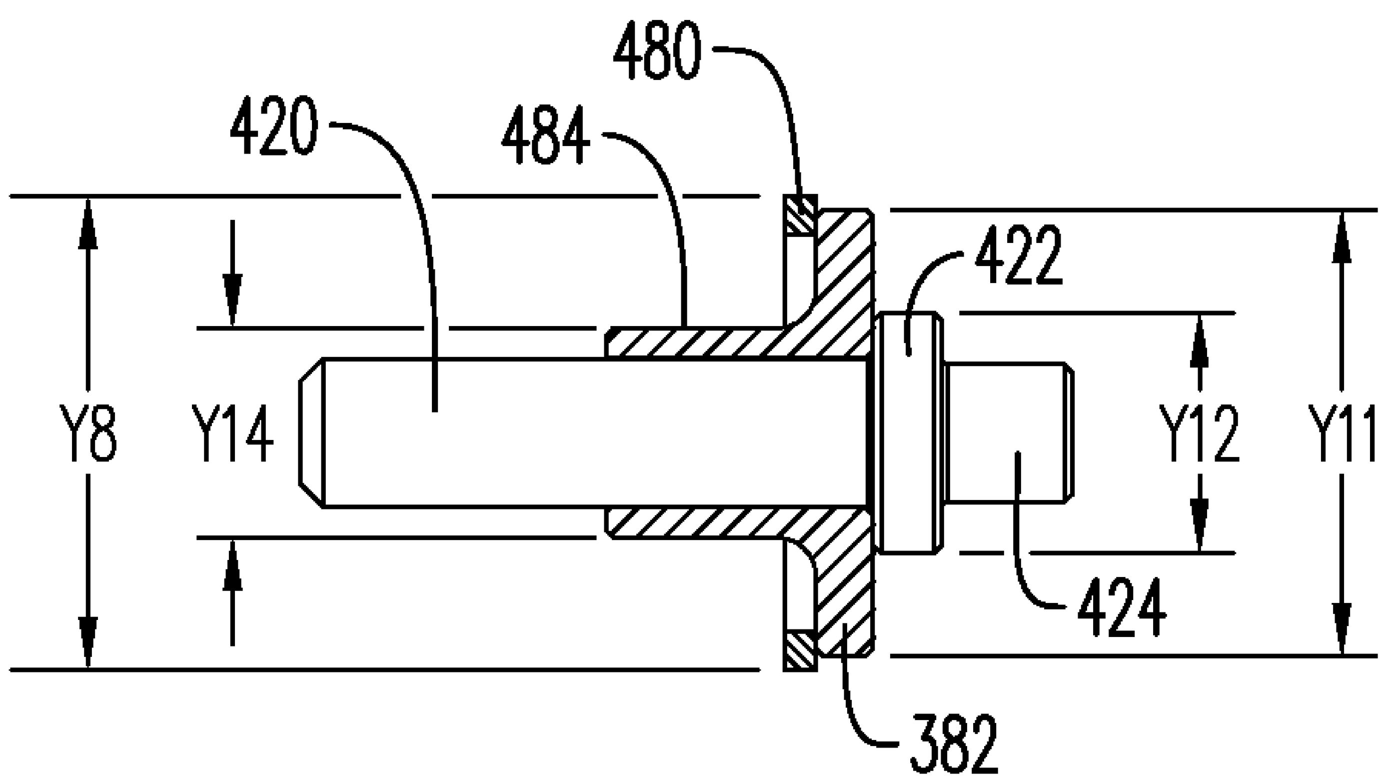

FIG. 26

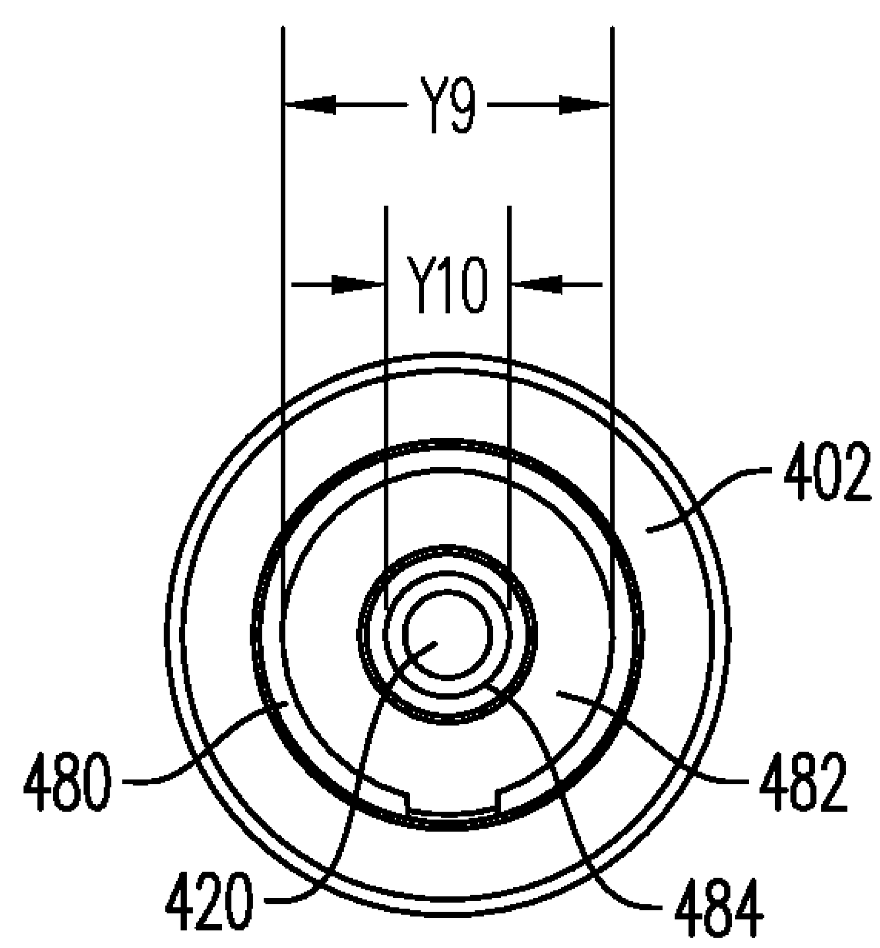

FIG. 27

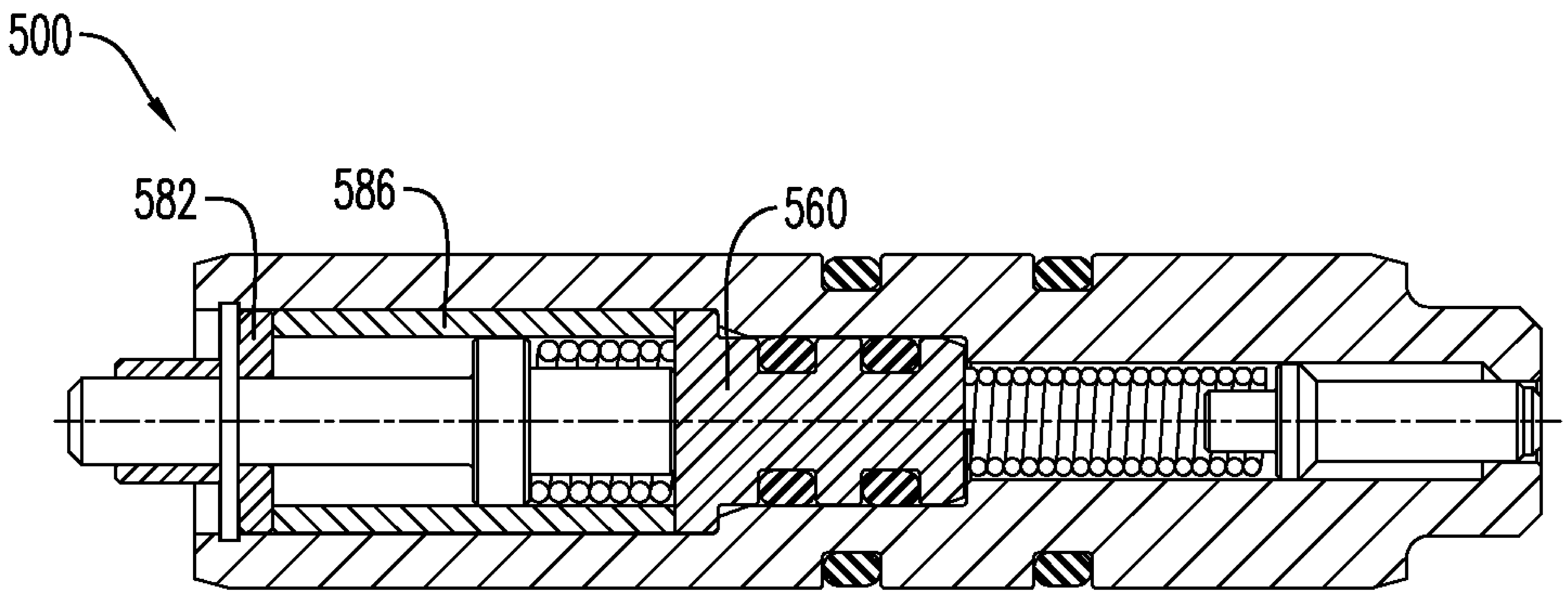

FIG. 28

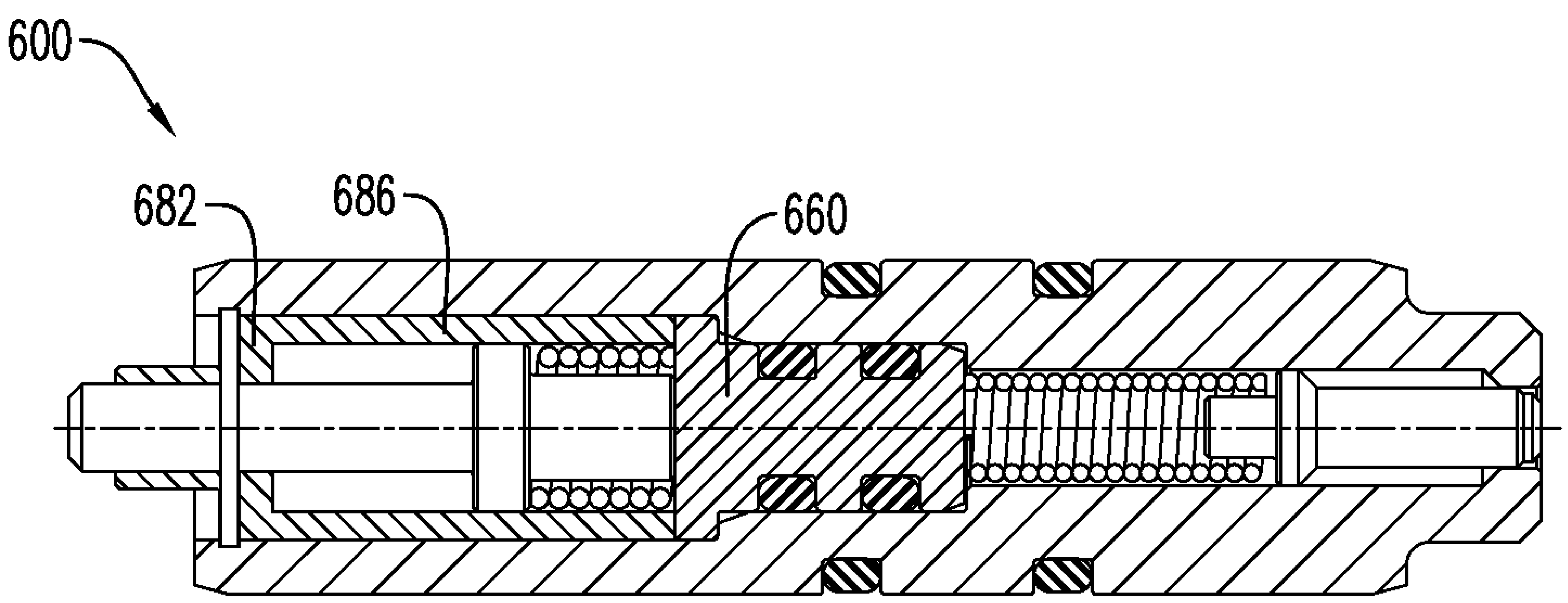

FIG. 29

ELECTRICAL CONNECTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of Ser. No. 16/819,270 filed Mar. 16, 2020, which is a continuation-in-part patent application of U.S. application Ser. No. 16/423,789 filed May 28, 2019, (issued as U.S. Pat. No. 10,982,941 on Apr. 20, 2021), which is a continuation of U.S. application Ser. No. 16/156,339 filed Oct. 10, 2018 (issued as U.S. Pat. No. 10,352,674 on Jul. 16, 2019), which is a continuation of U.S. application Ser. No. 16/056,944 filed Aug. 7, 2018 (issued as U.S. Pat. No. 10,365,078 on Jul. 30, 2019), which is a divisional patent application of U.S. application Ser. No. 15/612,953 filed Jun. 2, 2017 (issued as U.S. Pat. No. 10,066,921 on Sep. 4, 2018), which is a divisional patent application of U.S. application Ser. No. 15/068,786 filed Mar. 14, 2016 (issued as U.S. Pat. No. 9,784,549 on Oct. 10, 2017), which claims the benefit of U.S. Provisional Application No. 62/134,893 filed Mar. 18, 2015, each of which is incorporated herein by reference in its entirety.

FIELD

Described generally herein is a bulkhead assembly having a pivotable electric contact component for use with a downhole tool, that is, any piece of equipment that is used in a well.

BACKGROUND

In exploration and extraction of hydrocarbons, such as fossil fuels (e.g. oil) and natural gas, from underground wellbores extending deeply below the surface, various downhole tools are inserted below the ground surface and include sometimes complex machinery and explosive devices. Examples of the types of equipment useful in exploration and extraction, in particular for oil well drilling applications, include logging tools and perforation gun systems and assemblies. It is often useful to be able to maintain a pressure across one or more components, (that is, to provide a "pressure barrier"), as necessary to ensure that fluid does not leak into the gun assembly, for instance. It is not uncommon that components such as a bulkhead and an initiator are components in such perforating gun assemblies that succumb to pressure leakage.

Upon placement into the perforating gun assembly, one or more initiators, (typically a detonator or an igniter), have traditionally required physical connection of electrical wires. The electrical wires typically travel from the surface down to the perforating gun assembly, and are responsible for passing along the surface signal required to initiate ignition. The surface signal typically travels from the surface along the electrical wires that run from the surface to one or more detonators positioned within the perforating gun assembly. Passage of such wires through the perforating gun assembly, while maintaining a pressure differential across individual components, has proved challenging.

Assembly of a perforating gun requires assembly of multiple parts, which typically include at least the following components: a housing or outer gun barrel within which is positioned a wired electrical connection for communicating from the surface to initiate ignition, an initiator or detonator, a detonating cord, one or more charges which are held in an inner tube, strip or carrying device and, where necessary, one or more boosters. Assembly typically includes threaded

insertion of one component into another by screwing or twisting the components into place, optionally by use of a tandem-sub adapter. Since the wired electrical connection often must extend through all of the perforating gun assembly, it is easily twisted and crimped during assembly. Further, the wired electrical connections, to a detonator or initiator, usually require use of an electrical ground wire connectable to the electrical wire and extending through the housing in order to achieve a ground contact. When a ground contact is desired, the electrical ground wire must also be connected to an often non-defined part of the perforating gun assembly. Thus, the ground wire is sometimes wedged on or in between threads of hardware components and/or twisted around a metal edge of the housing of the perforating gun assembly. One issue with this arrangement is that it can be a source of intermittent and/or failed electrical contact. In addition, when a wired detonator is used it must be manually connected to the electrical wire, which has led to multiple problems. Due to the rotating assembly of parts, the electrical ground wires can become compromised, that is to say the electrical ground wires can become torn, twisted and/or crimped/nicked, or the wires may be inadvertently disconnected, or even mis-connected in error during assembly, not to mention the safety issues associated with physically and manually wiring live explosives.

According to the prior art and as shown in FIG. **1**, a wired bulkhead **10'** of the prior art is depicted. In a perforating gun assembly, the bulkhead **10'** may be utilized to accommodate electrical and ballistic transfer (via wired electric connection **170'**, shown with an insulator **172'** covering one end of the electrical contact component **20'**, which extends through the body of the bulkhead **10'**) to the electric connection of a next gun assembly in a string of gun assemblies, for as many gun assembly units as may be required depending on the location of underground oil or gas formation. Such bulkhead assemblies are usually provided with fixed pin contacts extending from either end of the assembly. Typically the bulkhead is employed to provide the electrical contact or feed-through in order to send electrical signals to the initiator or a type of switching system. In such applications, the pressure bulkhead is required to remain pressure sealed even under high temperatures and pressures as may be experienced in such applications, both during operation and also after detonation of the perforating gun, for instance, so that a neighboring perforating gun or downhole tool device does not become flooded with wellbore fluid or exposed to the wellbore pressure. Maintenance of the pressure differential across such devices occurs via usage of rubber components including o-rings **32'**, rubber stoppers and the like.

Such bulkhead assemblies are common components, particularly when a string of downhole tools is required, and is a pressure barrier or component through which electronic componentry and/or electrical wiring and electrical ground wiring must pass, (e.g. electric feed-through), and a need exists to provide such componentry with electric feed-through while maintaining a differential pressure across the component, and without compromising the electrical connection.

Improvements to the way electrical connections are accomplished in this industry include connections and arrangements as found in commonly assigned patent applications PCT/EP2012/056609 (in which an initiator head is adapted to easily introduce external wires into the plug without having to strip the wires of insulation beforehand) and PCT/EP2014/065752 (in which a wireless initiator is provided), which are incorporated herein by reference in their entireties.

The assembly described herein further solves the problems associated with prior known assemblies in that it provides, in an embodiment, an assembly that allows improved assembly in the field while maintaining the integrity of the electrical connection, as described in greater detail hereinbelow.

BRIEF DESCRIPTION

An exemplary embodiment an electrical connector may include a connector body extending along a longitudinal axis, a first electrical contact provided at a first end of the connector body, a first aperture provided in the first end of the connector body, a bore provided in an interior of the connector body and connected to the first aperture, and a conductive fixed body provided within the bore. The conductive fixed body may include a first contact surface on a first side of the conductive fixed body facing the first electrical contact along the longitudinal axis. A first spring may be provided in the bore between the first contact surface and the first electrical contact, and the first spring may be in contact with the first contact surface and the first electrical contact.

An exemplary embodiment of an electrical connector may include a connector body extending along a longitudinal axis, a first electrical contact provided at a first end of the connector body, a second electrical contact provided at a second end of the connector body, a first aperture provided in the first end of the connector body, a second aperture provided in the second end of the connector body, a bore provided in an interior of the connector body and connected to the first aperture, and a conductive fixed body provided within the bore. The conductive fixed body may include a first contact surface on a first side of the conductive fixed body facing the first electrical contact along the longitudinal axis and a second contact surface provided on a second side of the conductive fixed body facing the second electrical contact along the longitudinal axis. A first spring may be provided in the bore between the first contact surface and the first electrical contact, and the first spring may be in contact with the first contact surface and the first electrical contact. A second spring may be provided in the bore between the second contact surface and the second electrical contact, and the second spring may be in contact with the second contact surface and the second electrical contact.

An exemplary embodiment of an electrical connector may include a connector body extending along a longitudinal axis, a first electrical contact provided at a first end of the connector body, a first aperture provided in the first end of the connector body, a bore provided in an interior of the connector body, the bore being connected to the first aperture, and a conductive fixed body provided within the bore. The conductive fixed body may include a first contact surface on a first side of the conductive fixed body facing the first electrical contact along the longitudinal axis. A first spring may be provided in the bore between the first contact surface and the first electrical contact, and the first spring may be in contact with the first contact surface and the first electrical contact. The bore may include a first bore portion having a first bore diameter and a second bore portion axially adjacent to the first bore portion and having a second bore diameter larger than the first bore diameter. The connector body may further include an annular shoulder formed at a transition between the first bore portion and the second bore portion. The first contact surface may abut the annular shoulder. The first spring and at least a portion of the first electrical contact may be disposed within the first bore portion.

BRIEF DESCRIPTION OF THE FIGURES

A more particular description briefly described above will be rendered by reference to specific embodiments thereof that are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments and are not therefore to be considered to be limiting of its scope, exemplary embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. **1** is a perspective view of a bulkhead assembly according to the prior art;

FIG. **2** is a cross-sectional side view of a bulkhead assembly according to an aspect;

FIG. **3** is a cut-away perspective view of the bulkhead assembly of FIG. **2**;

FIG. **4** is a partially cut-away side view of the bulkhead assembly assembled within a perforating gun assembly according to an aspect;

FIG. **5** is a partially cut-away perspective view of the bulkhead assembly assembled within a perforating gun assembly according to an aspect;

FIG. **6** is a perspective view of a ground apparatus according to an aspect;

FIG. **7** is a top view of a ground apparatus according to an aspect;

FIG. **8** is a side view of a ground apparatus according to an aspect;

FIGS. **9**A-**9**C are perspective views showing a ground apparatus positioned on a bulkhead assembly according to an aspect;

FIG. **10** is a side view of a ground apparatus positioned on a bulkhead assembly for use with a wired initiator, according to an aspect;

FIG. **11** is a side view of a ground apparatus positioned on a bulkhead assembly for use with a wireless initiator, according to an aspect;

FIG. **12** is a cross-sectional view of a bulkhead assembly having a ground apparatus according to an aspect;

FIG. **13** is a partially cut-away side view a bulkhead assembly having a ground apparatus and assembled within a perforating gun assembly according to an aspect;

FIG. **14** is a side view of an electrical connector according to an exemplary embodiment;

FIG. **15** is a cross-sectional view of a connector body according to an exemplary embodiment;

FIG. **16** is a cross-sectional view of a fixed body according to an exemplary embodiment;

FIG. **17** is a cross-sectional view of an electrical connector at a rest position according to an exemplary embodiment;

FIG. **18** is a cross-sectional view of an electrical connector at a retracted position according to an exemplary embodiment;

FIG. **19** is a cross-sectional view of an electrical contact, washer, and retainer ring according to an exemplary embodiment;

FIG. **20** is an end view of an electrical connector according to an exemplary embodiment;

FIG. **21** is a side view of an electrical connector according to an exemplary embodiment;

FIG. **22** is a cross-sectional view of a connector body according to an exemplary embodiment;

FIG. **23** is a cross-sectional view of a fixed body according to an exemplary embodiment;

FIG. **24** is a cross-sectional view of an electrical connector at a rest position according to an exemplary embodiment;

FIG. **25** is a cross-sectional view of an electrical connector at a retracted position according to an exemplary embodiment;

FIG. **26** is a cross-sectional view of an electrical contact, washer, and retainer ring according to an exemplary embodiment;

FIG. **27** is an end view of an electrical connector according to an exemplary embodiment;

FIG. **28** is a cross-sectional view of an electrical connector according to an exemplary embodiment; and

FIG. **29** is a cross-sectional view of an electrical connector according to an exemplary embodiment.

Various features, aspects, and advantages of the embodiments will become more apparent from the following detailed description, along with the accompanying figures in which like numerals represent like components throughout the figures and text. The various described features are not necessarily drawn to scale, but are drawn to emphasize specific features relevant to embodiments.

DETAILED DESCRIPTION

Reference will now be made in detail to various embodiments. Each example is provided by way of explanation, and is not meant as a limitation and does not constitute a definition of all possible embodiments.

A bulkhead assembly is generally described herein, having particular use in conjunction with a downhole tool, and in particular to applications requiring the bulkhead assembly to maintain a pressure, and is thus commonly referred to as a pressure bulkhead assembly. In an embodiment, the bulkhead assembly is configured for use with a logging tool or a perforating gun assembly, in particular for oil well drilling applications. The bulkhead assembly provides an electrical contact component disposed within a body thereof, wherein at least a portion of the electrical contact component is configured to pivot about its own axis, without compromising its ability to provide a pressure and fluid barrier. A ground apparatus is generally described herein. The ground apparatus may have particular utility with various embodiments of the bulkhead assembly described herein. The ground apparatus provides an electrical connection for at least one ground wire and may be configured to pivot about its own axis when positioned on the bulkhead body of the bulkhead assembly, thereby providing continuous and/or successful electrical contact.

With reference to FIG. **2**, a bulkhead assembly **10** is provided and is further configured for sealing components positioned downstream of the bulkhead assembly **10** within a downhole tool. In an embodiment, the bulkhead assembly **10** is configured as a pressure-isolating bulkhead and is configured to withstand a pressure of at least about 20,000 psi (137.9 mPa). In an embodiment, the bulkhead assembly **10** is configured to withstand a pressure of at least about 30,000 psi (275.8 mPa). The bulkhead assembly **10** includes a bulkhead body **12** having a first end portion **13** and a second end portion **14** and a bore **17** extending therebetween. It is further envisioned that the bulkhead body **12** includes a first body portion **15** extending from the first end portion **13** towards a center of the bulkhead body **12**, and a second body portion **16**, extending from the second end portion **14** towards the center of the bulkhead body **12**. While it is contemplated that the bulkhead body **12** be made of thermoplastic materials (or otherwise electrically non-conductive materials), it is possible for the bulkhead body **12** to be made of other materials, such as metal (e.g., aluminum with a non-conductive coating). Although the first body portion **15** and the second body portion **16** are depicted as being roughly the same size or otherwise proportioned equally, it is contemplated that these body portions may be dissimilar in size or otherwise disproportionate.

The bulkhead body **12** may be formed as a unitary member or component. Methods of forming the bulkhead body **12** as a unitary member include but are not limited to injection molding and machining the component out of a solid block of material. In an embodiment, the injection molded bulkhead body **12** is formed into a solid material, in which typically a thermoplastic material in a soft or pliable form is allowed to flow around the electrical contact component **20** during the injection molding process.

The bulkhead body **12** includes an outer surface **30**, which is configured to be received in a tandem sub **150** as described in greater detail hereinbelow. The outer surface **30** typically includes one or more circumferential indentions **31**, which are configured for receiving an outer sealing member **32** in such a way as to seal components positioned downstream of the bulkhead assembly **10** and to withstand typical high pressures experienced in downhole applications.

According to an aspect, the bore **17** extends through the bulkhead body **12**, along an axis A-A and typically in the center of the body, and may vary in diameter across the length of the bulkhead body. With particular reference to FIG. **2**, the bore **17** may include three sections or portions of varying diameter, although it is possible to configure the bore **17** with one, two, three, or more sections. As depicted in FIG. **2** and in an embodiment, the bore **17** includes an end portion bore **17***a* extending through each of the first body portion **15** and the second body portion **16**, a central portion bore **17***b* and mid-portion bores **17***c* extending between the central portion bore **17***b* and the end portion bores **17***a* for a depth or length C. The length C is selected to optimize functionality of the slideable components as described in greater detail hereinbelow. As shown herein and in an embodiment, each end portion bore **17***a* has a smaller radius than the respective mid-portion bore **17***c*, while the central portion bore **17***b* has a larger radius than the mid-portion bores **17***c*.

The bulkhead assembly **10** further includes an electrical contact component **20** extending through the bore **17** of the bulkhead body **12**, such that at least a portion of the electrical contact component **20** is configured to pivot about its own axis A-A. Thus, the bulkhead assembly **10** has a pivotable electrical contact component **20**. The electrical contact component **20** is configured for electrical conductivity and feed-through of an electric signal. The electrical contact component **20** may thus be formed of any suitable electrically conductive material.

The electrical contact component **20** may include one or more of the following components: a contact pin **21** or wire (not shown), a biasing member **50** (FIG. **3**), and/or a central portion **40**. It will be understood by one of ordinary skill in the art that although terms like "central" are utilized, such terms are used to describe the positions of some components relative to other components. Although the component may literally be positioned centrally, it is also contemplated that positioning of the components may be de-centralized without detracting from the intended purpose.

In an embodiment and with particular reference to FIGS. **1** and **2**, the electrical contact component **20** includes one or more contact pins **21**, a wire connection (not shown) or combinations thereof. In other words, it may be possible to assemble the bulkhead assembly **10** according to an aspect in which a contact pin **21** is replaced by the wire at, for instance a first end **22**. Although this may limit the adaptability for the intended use, that is to freely pivot within the bulkhead to avoid binding, crimping or otherwise compromising the wire (and thus an electrical signal), having a single pivotable electrical contact component extending from an end of the bulkhead assembly **10** may still be advantageous over currently available assemblies.

According to an aspect, the electrical contact component **20** may include a plurality of contact pins **21**, and each of the contact pins **21** include the first end **22** and a second end **23**. In an embodiment, at least one of the contact pins **21** is slidably positioned within the bore **17** of the bulkhead body **12**. In an embodiment, the contact pin includes a pin head **26** extending from a pin body **27**. Typically, the contact pin may include a terminal contacting portion **28** extending from the pin body **27**, opposite the pin head **26** for ease of facilitating the electrical connection.

As shown in FIGS. **2** and **3**, the bulkhead assembly **10** of the depicted embodiment includes a first contact pin **24** positioned at least partially within the first body portion **15** and extending from the first end portion **13** to an exterior or outer surface **30** of the assembly **10**, while a second contact pin **25** is positioned at least partially within the second body portion **16** and extends from the second end portion **14** to the outer surface **30** of the assembly **10**.

In an embodiment, the central bore portion **17***b* is typically configured to receive the central portion **40** of the electrical contact component **20**, while a mid-portion bore **17***c* is typically configured to receive the pin head **26** and/or the biasing members **50** of the electrical contact component **20**. In an embodiment, the central portion **40** and a plurality of biasing members **50** (such as a coil spring) are positioned within the bore **17** of the bulkhead body **12** with the biasing members abutting at least a portion of the central portion **40**. In an embodiment, the central portion **40** of the electrical contact component **20** includes a disk-like central body **41** and arms **42** extending therefrom.

As depicted in FIGS. **2** and **3** and in an embodiment, the central portion bore **17***b* of the bore **17** includes a recessed portion **18**, which is recessed from the central portion bore and configured to receive a bore sealing member **19**. This seal will help to maintain the integrity of the bulkhead assembly **10** for sealing and maintaining pressure across the assembly as described in greater detail hereinbelow.

As shown herein, the plurality of biasing members **50** include a first biasing member **51** and a second biasing member **52**. The first biasing member **51** is positioned within the bore **17** of a first body portion **15** of the bulkhead body **12**, and the second biasing member **52** is positioned within the bore **17** of a second body portion **16** of the bulkhead body **12**. More particularly and in this embodiment, the biasing members **50** are positioned within the mid-portion bore **17***c*. In a further embodiment, the plurality of biasing members **50** abut the central portion **40**, and each of said biasing members **50** abuts at least one of the contact pins **21**. In an embodiment, the first contact pin **24** abuts the first biasing member **51** and the second contact pin **25** abuts the second biasing member **52**. It is further contemplated that it is possible to provide a rigid connection between at least one of the first contact pin **24** and the first biasing member **51** or the second contact pin **25** and the second biasing member **52**.

According to an aspect, the pin head **26** of the contact pin is sized to be slidably received within the mid-portion bore **17***c* of the bore **17** of the bulkhead body **12**. Thus, in a typical arrangement, the pin head **26** may have an enlarged radius relative to the radius of the pin body **27**. In this way, the pin head **26** will be received within the mid-portion **17***c*, while the pin body **27** extends through the end portion bore **17***a* of the first or second end portion **13**, **14**, respectively.

In operation, the contact pins **21** are capable of rotation or swiveling or twisting or pivoting, (all of which are functions referred to generically herein as "pivot," "pivotable," "pivoting"), about its own axis A-A as shown by arrows D, and are rotatable or pivotable in either direction. This ability to pivot, or to be pivotable, about its own axis can be very useful during the loading procedure of hardware of a downhole tool **100** such as a perforating gun assembly where the twisting of the electrical cable attached to the bulkhead assembly **10** (typically crimped or soldered) would otherwise cause the cable connection to snap off unintentionally. The pivot function described herein allows at least portions of the electrical contact component **20** to pivot without building up tension in the cable to a point of snapping. In addition, the biasing members **50** may also compensate for unfavorable tolerance stack-up in the perforating gun assembly **100**.

As shown herein, the axis A-A of the contact pins **21** coincides with the axis A-A of the bulkhead body **12**. Furthermore, the contact pins **21** are capable of sliding backwards and forwards in the direction shown by arrows B, and such movement is limited by biasing members **50**. In practice, the contact pin is capable of moving into and out of the body while restricted from leaving the bulkhead body **12** due to the smaller inner diameter of end portion bores **17***a*, and compressibility of biasing members **50** as the members **50** are pushed against the central portion **40**. It is anticipated that a thickness of each of the first end portion **13** and the second end portion **14** are sized sufficiently to stop or retain at least a portion of the contact pin **21**, and in an embodiment, to stop or retain the pin head **26** within the mid-portion bore **17***c*. Alternatively, it may be possible to fix or otherwise attach (rather than abut) each of the components of the electrical contact component **20** together (not shown). In other words, on one end of the electrical contact component **20**, the first contact pin **24** may be attached to the first biasing member **51**, which is attached to the central portion **40**, while at the other end of the component, the second contact pin **25** may be attached to the second biasing member **52**, which is attached to the central portion **40**. In this way, it may not be necessary to provide first end portion **13** and second end portion **14** to retain the assembly within the bulkhead body **12**.

In an embodiment, the bulkhead assembly **10** is able to maintain a higher pressure at the first end portion **13** of the bulkhead body **12** as compared to the second end **14** of the bulkhead body **12**, as depicted in an embodiment in, for instance, FIG. **5**. In this embodiment, the bulkhead assembly **10** is positioned within the downhole tool **100**, in this instance a perforating gun assembly. Any and all of the features of the bulkhead assembly **10** mentioned hereinabove are useful in the downhole tool **100** including the bulkhead assembly **10**.

Only a portion of the downhole tool **100** is depicted herein, including a tandem seal adapter or tandem sub **150**, in which the bulkhead assembly **10** is shown assembled within the perforating gun assembly **100**. In an embodiment, the bulkhead assembly **10** is configured for positioning within the tandem seal adaptor **150**. The tandem sub **150** is configured to seal inner components within the perforating gun housing from the outside environment using various sealing means. The tandem seal adapter **150** seals adjacent perforating gun assemblies (not shown) from each other, and houses the bulkhead assembly **10**. As shown herein, the wired electrical connection **170** is connected to the first end **22** of the electrical contact component **20** of the bulkhead assembly **10** via the first contact pin **24** (not shown). An insulator **172** covers the first contact pin **24** and in an embodiment provides a coating or insulating member, typically using heat shrinking, over the connecting wires of the wired electrical connection **170**.

In an embodiment, and as shown particularly in FIGS. **4** and **5**, the bulkhead assembly **10** functions to relay the electrical signal via the electrical contact component **20** to an initiator **140**, such as a detonator or igniter. In particular and as shown in FIG. **5**, the second contact pin **25** is in contact with a spring loaded electric contact, which is connected to the initiator **140**. In an embodiment and as shown herein, the first contact pin **24** (see, for instance, FIG. **2**, and which is covered by the insulator **172** in FIG. **5**) is configured for connecting to the wired electrical connection **170** and the second contact pin **25** is configured for wirelessly electrically contacting an electrical contact, such as a detonator electrical contacting component **142**, to transmit the electrical signal. In a further embodiment, the second contact pin **25** is configured for wirelessly electrically contacting an electrical contact of the initiator **140**.

With reference to FIGS. **6-7**, a ground apparatus **210** is provided and is configured for providing an electrical connection for at least one ground wire **212**. According to an aspect, the ground apparatus may be configured to be received by a receiving member **251** (substantially as shown in FIGS. **9**A-**9**C and described substantially hereinbelow). The ground apparatus **210** may provide a ground apparatus to the electrical contact component of the bulkhead assembly **10** by providing a simple means to ground/attach the ground wire **212**. (See, for instance, FIGS. **10-13**.)

According to an aspect, the ground apparatus **210** may include a plate **220** and a contact arm **240** extending from the plate **220**. The plate **220** may include a grounding body **230** including an upper surface **231** and a lower surface **233**. According to an aspect, the ground apparatus **210** includes a contact arm **240**, which may be formed integrally with and extend from the grounding body **230**. While FIG. **6** and FIG. **12** illustrates the contact arm **240** extending out of or away from the upper surface **231**, it is to be understood that in some embodiments, the contact arm **240** extends out of or away from the lower surface **233**. The contact arm **240** may include an inner portion **241** and an outer portion **242**, such that the inner portion **241** extends from the base **238** of the grounding body **230** and the outer portion **242** extends beyond the inner portion **241**. The outer portion **242** of the contact arm **240** may include a connecting means **243** for mechanically and electrically connecting to the ground wire **212**, thereby providing an electrical ground connection. The connecting means **243** may include, for example, plastic sheathing cables, electrical tape, a clip and insulator, and the like.

According to an aspect and as illustrated in FIG. **7**, the plate **220** of the ground apparatus **210** includes at least a semi-disc shape. The plate **220** may have any other shape, such as a rectangular shape. According to an aspect, the plate **220** includes a ductile bendable sheet metal having conductive properties. In an embodiment, the plate **220** includes aluminum, copper, copper alloys and or any other electrically conductive materials. According to an aspect, the contact arm **240** is formed integrally with the grounding body **230** by virtue of being formed from the partially cut or stamped-out section of the grounding body **230**.

The grounding body **230** may include an aperture **232**. As illustrated in FIG. **7**, the grounding body **230** may include the aperture **232** extending from a perimeter **234** of the grounding body **230** substantially inwards and substantially towards a central portion of the grounding body **230**. The arrangement and/or formation of the aperture **232** in the grounding body **230** may form fingers **237** on either side of the grounding body **230**. The fingers **237** may extend from a base **238** of the grounding body **230**. According to an aspect, the fingers **237** extend substantially from the base **238** towards the perimeter **234** of the grounding body **230**. In an embodiment, the length L of the fingers **237** defines the depth of the aperture **232** and is the distance from the base **238** of the grounding body **230** to the perimeter **234**. The length L may be of any size and shape that would enable the fingers **237** to engage with the receiving member **251**, as will be discussed in greater detail hereinbelow. According to an aspect, a distance D**1** defines the width of the aperture **232**, between the fingers **237**. In an embodiment, the distance D**1** is created by virtue of the stamped out section of the grounding body **230**, i.e., the D**1** is substantially same as a size and/or dimensions of the contact arm **240**.

With particular reference to FIG. **7**, the distance D**1** may include an inner distance D**2**, a central distance D**3** and an outer distance D**4**. According to an aspect, the central distance D**3** may have a larger size than the inner distance D**2** and/or the outer distance D**4**. According to an aspect, the central distance D**3** may be sized and adapted to provide the pivoting capabilities of the ground apparatus **210**. In an embodiment, the central distance D**3** is designed to have a substantially circular shape. According to an aspect, when the outer distance D**4** is smaller in size than the central distance D**3**, the outer distance D**4** provides retention capabilities when the ground apparatus **210** is snapped or otherwise positioned on, for example, the bulkhead assembly **10** and/or engaged with the receiving member **251**, as seen, for instance, in FIG. **9**A.

As illustrated in FIG. **8**, the contact arm **240** extends from the plate **220**, and thus is positioned away from the upper surface **231** of the grounding body **230**. According to an aspect, the contact arm **240** projects away from the plate **220** at an angle A°. The angle A° may be between about 10 degrees $A°_1$ and about 170 degrees $A°_3$. According to an aspect, the angle A° is between about 10 degrees $A°_1$ and about 90 degrees $A°_2$. As described hereinabove, the grounding body **230** may be configured for pivoting about its own axis when positioned on the electrical device and/or the receiving member **251**. In any event, the angle A° may be selected so that when the grounding body **230** pivots about its own axis, the ground wire **212** will not be torn, twisted and/or crimped/nicked, i.e., the ground wire **212** will not become compromised. In other words, the grounding apparatus **210** may be able to provide continuous and/or successful electrical connection for the ground wire **212** while also being pivotable on the bulkhead assembly **10** and/or the receiving member **251**, thereby helping to at least reduce and/or limit the safety issues associated with physically and manually wiring live explosives.

As illustrated in FIGS. **9**A-**9**C and according to an aspect, the ground apparatus **210** is removeably positioned on the receiving member **251** of the bulkhead assembly **10**. According to an aspect, the grounding body **230** is at least partially positioned in a groove **252** formed in the receiving member **251**. When positioned in the groove **252**, the grounding body **230** is pivotable about its own axis. In an embodiment, when the grounding wire **212** is attached to the contact arm **240** of the ground apparatus, the ground apparatus **210** is pivotable in such a manner that the grounding wire **212** will not become compromised. Further, by virtue of being attached to the ground apparatus **210**, the grounding wire **212** is also capable of being removeably positioned and/or connected to the receiving member **251**.

According to an aspect and as illustrated in FIGS. **9A-9B**, when the ground apparatus **210** is positioned on the receiving member **251**, the perimeter **234** of the grounding body **230** may have a shape that is substantially similar to the shape of the bulkhead assembly **10**. In some embodiments, the perimeter **234** of the grounding body **230** has a shape that is not similar to the shape of the bulkhead assembly **10** (not shown).

FIGS. **9A-9C** illustrate the ground apparatus **210** being removed from the receiving member **251**, according to an aspect. When the ground apparatus **210** is removed from the receiving member, it can be easily repositioned thereon without requiring additional devices, such as, for example, clips and/or fasteners. The grounding apparatus **210** may function as an integrated device having all the components required for providing continuous and/or successful electrical contact.

With reference to FIGS. **10-13** and according to an aspect, a bulkhead assembly **10** having an integrated ground apparatus is provided. The bulkhead assembly **10** is illustrated including a bulkhead body **12** and an electrical contact component **20**. According to an aspect, the bulkhead body **12** includes a first end portion **13**, a second end portion **14** and a bore **17** (see FIG. **12**) extending between the first end portion **13** and the second end portion **14**. The electrical contact component **20** may extend through the bore **17** of the bulkhead body **12**, such that at least a portion of the electrical contact component **20** is configured to pivot about its own axis. According to an aspect, the electrical contact component **20** is configured for electrical conductivity and feed-through of the electric signal.

With reference to FIGS. **10-11** and according to an aspect, the bulkhead assembly **10** includes the first contact pin **24** extending from the first end portion **13** and the second contact pin **25**, **25'** extending from the second end portion **14**, with the ground apparatus **210** positioned adjacent to the first end portion **13** of the bulkhead body **12**. According to an embodiment, and as illustrated in FIG. **10**, the first contact pin **24** is configured for connecting to the wired electrical connection **170** and the second contact pin **25'** is configured for providing a wired electrical connection to, for instance, a wired initiator (not shown), to transmit the electrical signal. In an alternative embodiment and as illustrated in FIG. **11**, the first contact pin **24** is configured for connecting to the wired electrical connection **170** and the second contact pin **25** is configured for providing a wireless electrical connection to the wireless detonator electrical contacting component **142**, (see, for instance, FIG. **5**), to complete the electrical connection and to transmit the electrical signal. According to an aspect, when the ground apparatus **210** is positioned within the groove **252** formed in the receiving member **251**, the ground apparatus **210** can rotate/swivel/pivot about the receiving member **251** in a manner that does not compromise the grounding wire **212**. According to an aspect, the pivot function of the ground apparatus **210** relative to the bulkhead assembly **10** prevents the grounding wire **212** from becoming torn, crimped/nicked, inadvertently disconnected from the receiving member **251**, and allows the ground apparatus **210** to pivot or twist around the receiving member **251** as the electrical contact component **20** pivots within the bulkhead body **12** of the bulkhead assembly **10**.

FIG. **13** illustrates a downhole tool **100** including the bulkhead assembly **10** having the integrated ground apparatus **210**, according to an aspect. The downhole tool **100** may include the tandem seal adapter **150** (FIG. **4**) and the ground apparatus **210** pivotally attached to or assembled on the bulkhead assembly **10** within the tandem seal adapter **150**, in such a manner that the inner components within the bulkhead assembly **10** are sealed within the tandem seal adapter **150**. In other words, the tandem seal adapter **150** may house and seal the bulkhead assembly **10** and its respective ground apparatus **210** from adjacent perforating gun assemblies (not shown).

In an embodiment, the bulkhead assembly **10** provides an improved apparatus for use with a wireless connection—that is, without the need to attach, crimp, cut or otherwise physically and manually connect external wires to the component. Rather, one or more of the connections may be made wirelessly, by simply abutting, for instance, electrically contactable components. For the sake of clarity, the term "wireless" does not refer to a WiFi connection, but rather to this notion of being able to transmit electrical signals through the electrical componentry without connecting external wires to the component.

In an embodiment, the bulkhead assembly **10** is provided that is capable of being placed into the downhole tool **100** with minimal effort. Specifically, bulkhead assembly **10** is configured for use in the downhole tool **100** and to electrically contactably form an electrical connection with the initiator **140** or other downhole device, for instance, to transmit the electrical signal without the need of manually and physically connecting, cutting or crimping wires as required in a wired electrical connection.

FIGS. **14-20** illustrate an exemplary embodiment of an electrical connector **300**. As seen in FIG. **14**, the electrical connector **300** may include a connector body **302** extending along a longitudinal axis **301**. The connector body **302** may be formed from thermoplastic materials or otherwise electrically non-conductive materials. Alternatively, the connector body **302** may be made of other materials, such as a metal (e.g., aluminum with a non-conductive coating). O-rings **304** may be provided on an outer surface of the connector body **302**. The exemplary embodiment of FIG. **14** shows two o-rings **304**, but it will be understood that the number of o-rings **304** may be varied to suit the desired application, such as a single o-ring **304** or three or more o-rings **304**. The o-rings **304** are an exemplary embodiment of a sealing member that may be used to help create a pressure barrier in order for the electrical conductor **300** to serve as a pressure-isolating bulkhead in an exemplary embodiment.

FIG. **14** further shows that the electrical connector **300** may include a first electrical contact **310** provided at a first end of the connector body **302** in the longitudinal direction. The first electrical contact **310** may be biased so as to rest at a first rest position if no external force is being applied to the first electrical contact **310** and may be structured so as to move from the first rest position to a first retracted position in response to an application of external force against the first electrical contact **310**. In other words, the first electrical contact **310** may be spring-loaded. The first electrical contact **310** may have a first electrical contact diameter X1, and may be dimensioned so that at least a portion of the first electrical contact **310** is positioned in the connector body **302**. FIG. **14** shows an exemplary embodiment in which the first electrical contact is formed as a contact pin. However, it will be understood that other forms and shapes may be used for the first electrical contact **310** as may be required for specific applications, including, but not limited to, female electrical contacts and plate contacts.

FIG. **14** further shows that the electrical connector **300** may include a second electrical contact **320** provided at a second end of the connector body **302**. The second electrical contact **320** may be biased so as to rest at a second rest position if no external force is being applied to the second electrical contact **320** and may be structured so as to move from the second rest position to a second retracted position in response to an application of external force against the second electrical contact **320**. In other words, the second electrical contact **320** may be spring-loaded. The second electrical contact **320** may have a second electrical contact diameter X2, and may be dimensioned so that at least a portion of the second electrical contact **320** is positioned in the connector body **302**. FIG. **14** shows an exemplary embodiment in which the second electrical contact is formed as a contact pin. However, it will be understood that other forms and shapes may be used for the second electrical contact **320** as may be required for specific applications, including, but not limited to, female electrical contacts and plate contacts.

FIG. **15** shows a cross section of an exemplary embodiment of the connector body **302**, the cross section being along a plane that includes the longitudinal axis **301**. The connector body **302** may include a bore **330** extending through the length of the connector body **302**. The bore **330** may include a first aperture **332** provided at a first end of the bore in the longitudinal direction. The first aperture **332** may have a first aperture diameter X3, which may be larger than the first electrical contact diameter X1. The bore **330** may further include a second aperture **334** provided at a second end of the bore **330** in the longitudinal direction.

The bore **330** may further include a first bore portion **340** provided between the first aperture **332** and the second aperture **334**. The first bore portion **340** may be axially adjacent to the first aperture **332**. The first bore portion **340** may have a first bore diameter X4. A first bore annular shoulder **336** may be formed at a transition between the first bore portion **340** and the first aperture **332**.

The bore **330** may further include a second bore portion **342** provided between the first bore portion **340** and the second aperture **334**. The second bore portion **342** may be axially adjacent to the first bore portion **340**. The second bore portion **342** may have a second bore diameter X5 that is larger than the first bore diameter X4. A second bore annular shoulder **341** may be formed at a transition between the second bore portion **342** and the first bore portion **340**.

The bore may further include a third bore portion **344** provided between the second bore portion **342** and the second aperture **334**. The third bore portion **344** may be axially adjacent to the second bore portion **342**. The third bore portion **344** may have a third bore diameter X6 that is larger than the second bore diameter X5. A third bore annular shoulder **343** may be provided at a transition between the third bore portion **344** and the second bore portion **342**. FIG. **15** further shows that a retainer groove **348** may be formed in an inner surface **346** of the third bore portion **344** at a position between the second bore portion **342** and the second aperture **334**. According to an exemplary embodiment, the retainer groove **348** extends along the circumference of the inner surface **346**. An exemplary embodiment of retainer groove **348** will be discussed in further detail herein.

FIG. **16** shows a cross section of an exemplary embodiment of a fixed body **360** that may be provided within the bore **330** of the connector body **302**, the cross section being along a plane that includes the longitudinal axis **301**. The fixed body **360** may be formed of an electrically conductive material. The fixed body **360** may include a first fixed body portion **362**. The first fixed body portion **362** may be cylindrical in shape. The first fixed body portion **362** may include grooves **364** provided in an outer circumferential surface **363** of the first fixed body portion **362**, and o-rings **366** may be provided in the grooves **364**. The exemplary embodiment of FIG. **16** shows two grooves **364** and two o-rings **366**, but it will be understood that the number of grooves **364** and o-rings **366** may be varied to suit the desired application, such as a single o-ring **366** or three or more o-rings **366**. The o-rings **366** are an exemplary embodiment of a sealing member that may be used to help create a pressure barrier in order for the electrical conductor **300** to serve as a pressure-isolating bulkhead in an exemplary embodiment. The first fixed body portion **362** may have a first fixed body diameter X7 that is larger than the first bore diameter X4 and smaller than the second bore diameter X5.

FIG. **16** further shows that the fixed body **360** may include a second fixed body portion **370**. The second fixed body portion **370** may be formed as a hollow cylinder coaxial with and axially adjacent to the first fixed body portion **362**. An annular fixed body shoulder **376** may be provided at a transition between the first fixed body portion **362** and the second fixed body portion **370**. The second fixed body portion **370** may have a second fixed body diameter X8 that is larger than the second bore diameter X5 and the first fixed body diameter X7, and smaller than the third bore diameter X6. The second fixed body portion **370** may define a fixed body interior space **374** positioned radially inward from the inner circumferential wall **372** of the second fixed body portion **370**. The fixed body interior space **374** may have an interior space diameter X9.

FIG. **16** further shows that the fixed body **360** may include a first contact surface **368** provided at a first end of the fixed body in the longitudinal direction and a second contact surface **369** provided within the fixed body interior space **374**.

FIG. **17** shows a cross section of an assembled electrical connector **300** taken along a plane that includes longitudinal axis **301**. As seen in FIG. **17**, the fixed body **360** is received within the connector body **302** such that the first fixed body portion **362** is received in the second bore portion **342** and the second fixed body portion **370** is received in the third bore portion **344**. The first contact surface **368** may abut the second bore annular shoulder **341** so as to prevent movement of the fixed body **360** in a first direction along the longitudinal axis **301**. Alternatively or in addition, the annular fixed body shoulder **376** may abut with the third bore annular shoulder **343** so as to prevent movement of the fixed body **360** in the first direction along the longitudinal axis **301**.

In the exemplary embodiment shown in FIG. **17**, the first electrical contact **310** may be disposed so as to extend through the first aperture **332**. Because the first aperture diameter X3 may be larger than the first electrical contact diameter X1, the first electrical contact **310** may be slidably disposed within the first aperture **332**. A first flange **312** may be provided axially adjacent to the first electrical contact **310** and disposed within the first bore portion **340**. The first flange **312** may be fixed to the first electrical contact **310**. In an exemplary embodiment, the first flange **312** may be integrally or monolithically formed with the first electrical contact **310**. The first flange **312** may have a first flange diameter X**10**, which may be larger than the first aperture diameter X**3** (see FIG. **15** for X**3**). Because the first flange diameter X**10** may be larger than the first aperture diameter X**3**, the first flange **312** cannot pass through the first aperture **332**, thereby retaining the first flange **312** within the first bore portion **340**. Additionally, the first flange diameter X**10** may be smaller than the first bore diameter X**4** (see FIG. **15** for X**4**), so that the first flange **312** may be slidably disposed within the first bore portion **340**.

FIG. **17** further shows that, in an exemplary embodiment, a first post **314** may be provided axially adjacent to the first flange **312** and disposed within the first bore portion **340**. The first post **314** may have a first post diameter smaller than the first flange diameter X**10**. The first post **314** may be fixed to the first flange **312**. Further, the first post **314** may be integrally or monolithically formed with the first flange **312**. In an exemplary embodiment, the first electrical contact **310**, the first flange **312**, and the first post **314** may be formed of an electrically conductive material.

As further seen in FIG. **17**, an exemplary embodiment may include a biasing member such as a first spring **350** provided in the first bore portion **340**. The first post **314** may fit inside the first spring **350** such that a first end of the first spring **350** abuts against the first flange **312**. A second end of the spring **350** may abut against the first contact surface **368** of the fixed body **362**. The first spring **350** may be arranged so as to provide a biasing force that pushes the first flange **312**, and consequently, the first electrical contact **310**, away from the first contact surface **368**. In the exemplary embodiment shown in FIG. **17**, there is no external force acting on the first electrical contact **310**, so the first spring **350** has extended to a rest position in which the first flange **312** is abutting against the first bore annular shoulder **336**. The first spring **350** may be formed of an electrically conductive material. Additionally, as the spring **350** is not necessarily fixed to the first flange **312**, the first post **314**, or the fixed body **360**, it will be understood that the first electrical contact **310** is rotatable with respect to the connector body **302**. Even if the first spring **350** were to be fixed to the first electrical contact **310** and the fixed body **360**, torsion in the first spring **350** would still allow for at least some rotation of the first electrical contact **310** relative to the connector body **302**.

FIG. **17** further shows that a retainer ring **380** may be provided in the third bore portion **344**. The retainer ring **380** may fit into the retainer groove **348** show in FIG. **15**. The retainer ring **380** may have an outer retainer ring diameter X**15** (see FIG. **19**) that is larger than the third bore diameter X**6**, and an inner retainer ring diameter X**16** (see FIG. **20**). Additionally, a washer **382** may be provided between the fixed body **360** and the retainer ring **380**. In an exemplary embodiment, the second fixed body portion **370** may abut with the washer **382** so as to fix the washer **382** between the second fixed body portion **370** and the retainer ring **380**. The washer **382** may have an outer washer diameter X**12** (see FIG. **19**) that is smaller than the third bore diameter X**6** such that the washer **382** fits within the third bore portion **344**. The outer washer diameter X**12** may also be larger than the inner retainer ring diameter X**16**, such that the washer **382** is retained within the third bore portion **344** by the retainer ring **380**. The washer **382** may have an inner washer diameter X**13** (see FIG. **30**) that is larger than the second electrical contact diameter X**2**, such that the second electrical contact **320** may be slidably disposed through washer **382**. In an exemplary embodiment, the washer **382** may further include a washer sleeve **384** that extends in the longitudinal direction through the retainer ring **380**. The washer sleeve **384** may have the same inner washer diameter X**13** (see FIG. **20**) as the washer **382**, and the washer sleeve may have an outer washer sleeve diameter X**14** that is smaller than the inner retainer ring diameter X**16**.

In the exemplary embodiment shown in FIG. **17**, the second electrical contact **320** may be disposed so as to extend through the washer **382** and the washer sleeve **384**. Because the inner washer diameter X**13** is larger than second electrical contact diameter X**2**, the second electrical contact **320** may be slidably disposed through the washer **382**. A second flange **322** may be provided axially adjacent to the second electrical contact and disposed within the fixed body interior space **374**. The second flange **322** may be fixed to the second electrical contact **320**. In an exemplary embodiment, the second flange **322** may be fixed to the second electrical contact **320**. In a further exemplary embodiment, the second flange **322** may be integrally or monolithically formed with the second electrical contact **320**. The second flange **322** may have a second flange diameter X**11** (see FIG. **19**), which may be larger than the inner washer diameter X**13**. Because the second flange diameter X**11** may be larger than the inner washer diameter X**13**, the second flange **322** cannot pass through the washer **382**, thereby retaining the second flange **322** within the fixed body interior space **374**. Additionally, the second flange diameter X**11** may be smaller than the interior space diameter X**9**, so that the second flange **322** may be slidably disposed within the fixed body interior space **374**.

FIG. **17** further shows that, in an exemplary embodiment, a second post **324** may be provided axially adjacent to the second flange **322** and disposed within the fixed body interior space **374**. The second post **324** may have a second post diameter smaller than the second flange diameter X**11**. The second post **324** may be fixed to the second flange **322**. Further, the second post **324** may be integrally or monolithically formed with the second flange **322**. In an exemplary embodiment, the second electrical contact **320**, the second flange **322**, and the second post **324** may be formed of an electrically conductive material.

As further see in FIG. **17**, an exemplary embodiment may include a biasing member such as a second spring **352** provided in the fixed body interior space **374**. The second post **324** may fit inside the second spring **352** such that a first end of the second spring **352** abuts against the second flange **322**. A second end of the spring **352** may abut the second contact surface **369** of the fixed body **362**. The second spring **352** may be arranged so as to provide a biasing force that pushes the second flange **322**, and consequently, the second electrical contact **320** away from the second contact surface **369**. In the exemplary embodiment shown in FIG. **17**, there is no external force acting on the second electrical contact **320**, so the second spring **352** has extended to a rest position in which the second flange **322** is abutting against the washer **382**. The second spring **352** may be formed of an electrically conductive material. Additionally, as the second spring **352** is not necessarily fixed to the second flange **322**, the second post **324**, or the fixed body **360** it will be understood that the second electrical contact **320** is rotatable with respect to the connector body **302**. Even if the second spring **352** were to be fixed to the second electrical contact **320** and the fixed body **360**, torsion in the second spring **352** would still allow for at least some rotation of the second electrical contact **320** relative to the connector body **302**.

FIG. **18** shows an exemplary embodiment in which a first external force **390** has been applied to the first electrical contact **310** and a second external force **392** has been applied to the second electrical contact **320**. In other words, the first electrical contact **310** and the second electrical contact **320** have been moved to a retracted position due to the first external force **390** and the second external force **392**. The first external force **390** and the second external force **392** may represent, for example, other electrical components that have fixed terminals pressing against the first electrical contact **310** and the second electrical contact **320**. In FIG. **18**, the application of the first external force **390** and the second external force **392** has compressed the first spring **350** and the second spring **352**, thereby causing the first electrical contact **310** and the second electrical contact **320** to slide into the connector body **302**. The biasing force of the first spring **350** pushes the first electrical contact **310** back against the first external force **390**, thereby helping to ensure a secure contact between the first electrical contact **310** and the external contact generating the first external force **390**. Similarly, the biasing force of the second spring **352** pushes the second electrical contact **320** back against the second external force **392**, thereby helping to ensure a secure contact between the second electrical contact **320** and the external contact generating the second external force **392**.

It has been described herein with reference to an exemplary embodiment of the electrical connector **300** that the first electrical contact **310**, the first flange **312**, the first post **314**, the first spring **350**, the fixed body **360**, the second spring **352**, the second post **324**, the second flange **322**, and the second electrical contact **320** are each made of an electrically conductive material. This allows for electrical conductivity to be provided through the electrical connector **300**, thereby helping to provide for feedthrough of electrical signals in a system of perforating guns connected via the electrical connector **300**.

FIGS. **21-27** illustrate another exemplary embodiment of an electrical connector **400**. As seen in FIG. **21**, the electrical connector **400** may include a connector body **402** extending along a longitudinal axis **401**. O-rings **404** may be provided on an outer surface of the connector body **402**. The exemplary embodiment of FIG. **21** shows two o-rings **404**, but it will be understood that the number of o-rings **404** may be varied to suit the needs of the desired application, such as a single o-ring **404** or three or more o-rings **404**. The o-rings **404** are an exemplary embodiment of a sealing member that may be used to help create a pressure barrier in order for the electrical conductor **400** to serve as a pressure-isolating bulkhead in an exemplary embodiment.

FIG. **21** further shows that the electrical connector **400** may include a first electrical contact **410** provided at a first end of the connector body **402** in the longitudinal direction. The first electrical contact **410** may be biased so as to rest at a first rest position if no external force is being applied to the first electrical contact **410**. The first electrical contact **410** may be structured so as to move from the first rest position to a first retracted position in response to an application of external force against the first electrical contact **410**. In other words, the first electrical contact **410** may be spring-loaded. The first electrical contact **410** may have a first electrical contact diameter Y**1**. FIG. **21** shows an exemplary embodiment in which the first electrical contact **410** is formed as a contact pin. However, it will be understood that other forms and shapes may be used for the first electrical contact **410** as may be required for specific applications, including, but not limited to, female electrical contacts and plate contacts.

FIG. **21** further shows that the electrical connector **400** may include a second electrical contact **420** provided at a second end of the connector body **402**. The second electrical contact **420** may be biased so as to rest at a second rest position if no external force is being applied to the second electrical contact **420**. The second electrical contact **420** may be structured so as to move from the second rest position to a second retracted position in response to an application of external force against the second electrical contact **420**. In other words, the second electrical contact may be spring loaded. The second electrical contact **420** may have a second electrical contact diameter Y**2**. FIG. **21** shows an exemplary embodiment in which the second electrical contact **420** is formed is formed as a contact pin. However, it will be understood that other forms and shapes may be used for the second electrical contact **420** as bay be required for specific applications, including, but not limited to, female electrical contacts and plate contacts.

FIG. **22** shows a cross section of an exemplary embodiment of the connector body **402**, the cross section being along a plane that includes the longitudinal axis **401**. The connector body **402** may include a bore **430** extending through the length of the connector body **402**. The bore **430** may include a first aperture **432** provided at a first end of the bore **430** in the longitudinal direction. The first aperture **432** may have a first aperture diameter Y**3**, which may be larger than the first electrical contact diameter Y**1**. The bore **430** may further include a second aperture **434** provided at a second end of the bore **430** in the longitudinal direction.

The bore **430** may further include a first bore portion **440** provided between the first aperture **432** and the second aperture **434**. The first bore portion **440** may be axially adjacent to the first aperture **432**. The first bore portion **440** may have a first bore diameter Y**4**. A first bore annular shoulder **436** may be formed at a transition between the first bore portion **440** and the first aperture **432**.

The bore may further include a second bore portion **442** provided between the first bore portion **440** and the second aperture **434**. The second bore portion **442** may be axially adjacent to the first bore portion **440**. The second bore portion **342** may have a second bore diameter Y**5** that is larger than the first bore diameter Y**4**. A second bore annular shoulder **441** may be formed at a transition between the second bore portion **442** and the first bore portion **440**. FIG. **22** further shows that a retainer groove **448** may be formed in an inner circumferential surface **446** of the second bore portion **442** at a position between the first bore portion **440** and the second aperture **434**. An exemplary embodiment of retainer groove **448** will be discussed in further detail herein.

FIG. **23** shows a cross section of an exemplary embodiment of a fixed body **460** that may be provided within the bore **430** of the connector body **402**, the cross section being along a plane that includes the longitudinal axis **401**. The fixed body **460** may be formed of an electrically conductive material. The fixed body **460** may include a hollow cylinder **462** that is capped by a plate **465** at a first end of the hollow cylinder **462**. The fixed body **460** may have a fixed body diameter Y**13**, which may be larger than the first bore diameter Y**4** and smaller than the second bore diameter Y**5**. The hollow cylinder **462** may define a fixed body interior space **474** positioned radially inward from the inner circumferential walls **472** of the hollow cylinder **462**. The fixed body interior space **474** may have an interior space diameter Y**6**. The fixed body **460** may include grooves **464** provided in an outer circumferential surface **463** of the fixed body **460**, and o-rings **466** may be provided in the grooves **464**. The exemplary embodiment of FIG. **23** shows two grooves **464** and two o-rings **466**, but it will be understood that the number of the grooves **464** and the o-rings **466** may be varied to suit the desired application, such as a single o-ring

466 or three or more o-rings 466. Additionally, while FIG. 23 shows that the o-rings 466 are provided on an outer peripheral surface of hollow cylinder 462, it will be understood that the one or more o-rings 466 may be provided on an outer peripheral surface of plate 465, provided plate 465 has sufficient thickness in the longitudinal direction of fixed body 460. The o-rings 466 are an exemplary embodiment of a sealing member that may be used to help create a pressure barrier in order for the electrical conductor 400 to serve as a pressure-isolating bulkhead in an exemplary embodiment. FIG. 23 further shows that the plate 465 may have a first plate surface 468 and a second plate surface 469 opposite to the first plate surface 468.

FIG. 24 shows a cross section of an assembled electrical connector 400 taken along a plane that include longitudinal axis 301. As seen in FIG. 24, the fixed body 460 is received within the second bore portion 442 of the connector body 402. The first plate surface 468 may abut the second bore annular shoulder 441 so as to prevent movement of the fixed body 460 in a first direction along the longitudinal axis 401.

In the exemplary embodiment shown in FIG. 24, the first electrical contact 410 may be disposed so as to extend through the first aperture 432. Because the first aperture diameter Y3 may be larger than the first electrical contact diameter Y1, the first electrical contact 410 may be slidably disposed within the first aperture 432. A first flange 412 may be provided axially adjacent to the first electrical contact 410 and disposed within the first bore portion 440. The first flange 412 may be fixed to the first electrical contact 410. In an exemplary embodiment the first flange 412 may be integrally or monolithically formed with the first electrical contact 410. The first flange 412 may have a first flange diameter Y7, which may be larger than the first aperture diameter Y3. Because the first flange diameter Y7 may be larger than the first aperture diameter Y3, the first flange 412 cannot pass through the first aperture 432, thereby retaining the first flange 412 within the first bore portion 440. Additionally, the first flange diameter Y7 may be smaller than the first bore diameter Y4, so that the first flange 412 may be slidably disposed within the first bore portion 440.

FIG. 24 further shows that, in an exemplary embodiment, a first post 414 may be provided axially adjacent to the first flange 412 and disposed within the first bore portion 440. The first post 414 may have a first post diameter smaller than the first flange diameter Y7. The first post 414 may be fixed to the first flange 412. Further, the first post 414 may be integrally or monolithically formed with the first flange 412. In an exemplary embodiment, the first electrical contact 410, the first flange 412, and the first post 414 may be formed of an electrically conductive material.

As further seen in FIG. 24, an exemplary embodiment may include a biasing member such as a first spring 450 provided in the first bore portion 440. The first post 414 may fit inside the first spring 450 such that a first end of the first spring 450 abuts against the first flange 412. A second end of the spring 350 may abut against the first plate surface 468 of the fixed body 460. The first spring 450 may be arranged so as to provide a biasing force that pushes the first flange 412, and consequently, the first electrical contact 410, away from the first plate surface 368. In the exemplary embodiment shown in FIG. 24, there is no external force acting on the first electrical contact 410, so the first spring 450 has extended to a rest position in which the first flange 412 is abutting against the first bore annular shoulder 436. The first spring 450 may be formed of an electrically conductive material. Additionally, as the spring 450 is not necessarily fixed to the first flange 412, the first post 414, or the fixed body 460, it will be understood that the first electrical contact 410 is rotatable with respect to the connector body 402. Even if the first spring 450 were to be fixed to the first electrical contact and the fixed body 460, torsion in the first spring 450 would still allow for at least some rotation of the first electrical contact 410 relative to the connector body 402.

FIG. 24 further shows that a retainer ring 480 may be provided in the second bore portion 442. The retainer ring 480 may first into the retainer groove 448 shown in FIG. 22. The retainer ring 480 may have an outer retainer ring diameter Y8 (see FIG. 26) that is larger than the second bore diameter Y5, and an inner retainer ring diameter Y9 (see FIG. 27). Additionally, a washer 482 may be provided between the fixed body 460 and the retainer ring 480. In an exemplary embodiment the fixed body 460 may abut with the washer 482 so as to fix the washer 482 between the fixed body 460 and the retainer ring 480. The washer 482 may have an outer washer diameter Y11 (see FIG. 26) that is smaller than the second bore diameter Y5 such that the washer 482 fits within the second bore portion 442. The outer washer diameter Y11 may also be larger than the inner retainer ring diameter Y9 such that the washer 482 is retained within the second bore portion 442 by the retainer ring 480. The washer 482 may have an inner washer diameter Y10 (see FIG. 27) that is larger than the second electrical contact diameter Y2, such that the second electrical contact 420 may be slidably disposed through washer 482. In an exemplary embodiment, the washer 482 may further include a washer sleeve 484 that extends in the longitudinal direction through the retainer ring 480. The washer sleeve 484 may have the same inner washer diameter Y10 as the washer 482, and the washer sleeve may have an outer washer sleeve diameter Y14 that is smaller than the inner retainer ring diameter Y9.

In the exemplary embodiment shown in FIG. 24, the second electrical contact 420 may be disposed so as to extend through the washer 482 and the washer sleeve 484. Because the inner washer diameter Y10 is larger than the second electrical contact diameter Y2, the second electrical contact 420 may be slidably disposed through the washer 482 and the washer sleeve 484. A second flange 422 may be provided axially adjacent to the second electrical contact and disposed within the fixed body interior space 474. The second flange 422 may be fixed to the second electrical contact 420. In an exemplary embodiment, the second flange 422 may be fixed to the second electrical contact 420. In a further exemplary embodiment, the second flange 422 may be integrally or monolithically formed with the second electrical contact 420. The second flange 422 may have a second flange diameter Y12 (see FIG. 26), which may be larger than the inner washer diameter Y10. Because the second flange diameter Y12 may be larger than the inner washer diameter Y10, the second flange 422 cannot pass through the washer 482, thereby retaining the second flange 422 within the fixed body interior space 474. Additionally, the second flange diameter Y12 may be smaller than the interior space diameter Y6, so that the second flange 422 may be slidably disposed within the fixed body interior space 474.

FIG. 24 further shows that, in an exemplary embodiment, a second post 424 may be provided axially adjacent to the second flange 422 and disposed within the fixed body interior space 474. The second post 424 may have a second post diameter smaller than the second flange diameter Y12. The second post 424 may be fixed to the second flange 422. Further, the second post 424 may be integrally or monolithically formed with the second flange **422**. In an exemplary embodiment, the second electrical contact **420**, the second flange **422**, and the second post **424** may be formed of an electrically conductive material.

As further seen in FIG. **24**, an exemplary embodiment may include a biasing member such as a second spring **452** provided in the fixed body interior space **474**. The second post **424** may fit inside the second spring **452** such that a first end of the second spring **452** abuts against the second flange **422**. A second end of the spring **452** may abut the second plate surface **469** of the plate **465**. The second spring **452** may be arranged so as to provide a biasing force that pushes the second flange **422**, and consequently, the second electrical contact **420** away from the second plate surface **469**. In the exemplary embodiment shown in FIG. **24**, there is no external force acting on the second electrical contact **420**, so the second spring **452** has extended to a rest position in which the second flange **422** is abutting against the washer **482**. The second spring **452** may be formed of an electrically conductive material. Additionally, as the second spring **452** is not necessarily fixed to the second flange **422**, the second post **424**, or the fixed body **360**, it will be understood that the second electrical contact **420** is rotatable with respect to the connector body **402**. Even if the second spring **452** were to be fixed to the second electrical contact **420** and the fixed body **360**, torsion in the second spring **452** would still allow for at least some rotation of the second electrical contact **420** relative to the connector body **402**.

FIG. **25** shows an exemplary embodiment in which a first external force **490** has been applied to the first electrical contact **410** and a second external force **492** has been applied to the second electrical contact **420**. In other words, the first electrical contact **410** and the second electrical contact **420** have been moved to a retracted position due to the first external force **490** and the second external force **492**. The first external force **490** and the second external force **492** may represent, for example, other electrical components that have fixed terminals against the first electrical contact **410** and the second electrical contact **420**. In FIG. **25**, the application of the first external force **490** and the second external force **492** has compressed the first spring **450** and the second spring **452**, thereby causing the first electrical contact **410** and the second electrical contact **420** to slide into the connector body **402**. The biasing force of the first spring **450** pushes the first electrical contact **410** back against the first external force **490**, thereby helping to ensure a secure contact between the first electrical contact **410** and the external contact generating the first external force **490**. Similarly, the biasing force of the second spring **452** pushes the second electrical contact **420** back against the second external force **492**, thereby helping to ensure a secure contact between the second electrical contact **420** and the external contact generating the second external force **492**.

While the exemplary embodiment of FIG. **17** shows the second fixed body portion **370** monolithically formed with the first fixed body portion **362**, it will be understood that alternative embodiments are possible. For example, in another exemplary embodiment of an electrical connector **500** shown in FIG. **28**, a spacer **586** may be provided between a fixed body **560** and a washer **582**. The spacer **586** may be shaped as a hollow cylinder, and may be formed of a material such as a plastic or resin that could be injection molded or 3-D printed. Alternatively, FIG. **29** shows an exemplary embodiment of an electrical connector **600** in which a hollow cylinder **686** is integrally and/or monolithically formed with washer **682**. Hollow cylinder **686** may extend in a longitudinal direction to abut with fixed body **660**.

The components and methods illustrated are not limited to the specific embodiments described herein, but rather, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. Such modifications and variations are intended to be included. Further, steps described in the method may be utilized independently and separately from other steps described herein.

While the apparatus and method have been described with reference to preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope. In addition, many modifications may be made to adapt a particular situation or material to the teachings without departing from the essential scope thereof. In the interest of brevity and clarity, and without the need to repeat all such features, it will be understood that any feature relating to one embodiment described herein in detail, may also be present in an alternative embodiment. As an example, it would be understood by one of ordinary skill in the art that if the electrical contact component **20** of one embodiment is described as being formed of an electrically conductive material, that the electrical contact component **20** described in the alternative embodiment is also formed of an electrically conductive material, without the need to repeat all such features.

In this specification and the claims that follow, reference will be made to a number of terms that have the following meanings. The singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Furthermore, references to "one embodiment" are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Terms such as "first," "second," etc. are used to identify one element from another, and unless otherwise specified are not meant to refer to a particular order or number of elements.

As used herein, the terms "may" and "may be" indicate a possibility of an occurrence within a set of circumstances; a possession of a specified property, characteristic or function; and/or qualify another verb by expressing one or more of an ability, capability, or possibility associated with the qualified verb. Accordingly, usage of "may" and "may be" indicates that a modified term is apparently appropriate, capable, or suitable for an indicated capacity, function, or usage, while taking into account that in some circumstances the modified term may sometimes not be appropriate, capable, or suitable. For example, in some circumstances an event or capacity can be expected, while in other circumstances the event or capacity cannot occur—this distinction is captured by the terms "may" and "may be."

As used in the claims, the word "comprises" and its grammatical variants logically also subtend and include phrases of varying and differing extent such as for example, but not limited thereto, "consisting essentially of" and "consisting of."

Advances in science and technology may make equivalents and substitutions possible that are not now contemplated by reason of the imprecision of language; these variations should be covered by the appended claims. This written description uses examples, including the best mode, and also to enable any person of ordinary skill in the art to practice, including making and using any devices or systems and performing any incorporated methods. The patentable scope is defined by the claims, and may include other examples that occur to those of ordinary skill in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. An electrical connector comprising:
a connector body extending along a longitudinal axis;
a first electrical contact provided at a first end of the connector body;
a first aperture provided in the first end of the connector body;
a bore provided in an interior of the connector body, the bore being connected to the first aperture;
a conductive fixed body provided within the bore, the conductive fixed body comprising a first contact surface on a first side of the conductive fixed body facing the first electrical contact along the longitudinal axis; and
a first spring provided in the bore between the first contact surface and the first electrical contact, the first spring being in contact with the first contact surface and the first electrical contact.

2. The electrical connector of claim **1**, wherein a position of the conductive fixed body is fixed relative to the connector body.

3. The electrical connector of claim **1**, wherein the first electrical contact is a first contact pin extending through the first aperture.

4. The electrical connector of claim **3**, wherein:
the first contact pin comprises a first flange disposed within the bore; and
a diameter of the first flange is larger than a diameter of the first aperture.

5. The electrical connector of claim **4**, wherein the first spring abuts the first flange.

6. The electrical connector of claim **1**, wherein the first electrical contact is rotatable around the longitudinal axis with respect to the connector body.

7. The electrical connector of claim **1**, further comprising a first o-ring provided between the conductive fixed body and the connector body in a radial direction perpendicular to the longitudinal axis.

8. The electrical connector of claim **1**, further comprising a first o-ring provided on an outer surface of the connector body.

9. The electrical connector of claim **1**, wherein the conductive fixed body further comprises:
a first fixed body portion having a first fixed body diameter; and
a second fixed body portion axially adjacent to the first fixed body portion and having a second fixed body diameter larger than the first fixed body diameter.

10. The electrical connector of claim **1**, wherein the first contact surface of the conductive fixed body is substantially perpendicular to the longitudinal axis.

11. An electrical connector comprising:
a connector body extending along a longitudinal axis;
a first electrical contact provided at a first end of the connector body;
a second electrical contact provided at a second end of the connector body;
a first aperture provided in the first end of the connector body;
a second aperture provided in the second end of the connector body;
a bore provided in an interior of the connector body, the bore being connected to the first aperture;
a conductive fixed body provided within the bore, the conductive fixed body comprising a first contact surface on a first side of the conductive fixed body facing the first electrical contact along the longitudinal axis;
a second contact surface provided on a second side of the conductive fixed body facing the second electrical contact along the longitudinal axis;
a first spring provided in the bore between the first contact surface and the first electrical contact, the first spring being in contact with the first contact surface and the first electrical contact; and
a second spring provided in the bore between the second contact surface and the second electrical contact, the second spring being in contact with the second contact surface and the second electrical contact.

12. The electrical connector of claim **11**, wherein the second electrical contact is a second contact pin extending through the second aperture.

13. The electrical connector of claim **11**, wherein:
the conductive fixed body further comprises:
a first fixed body portion having a first fixed body diameter; and
a second fixed body portion axially adjacent to the first fixed body portion and having a second fixed body diameter larger than the first fixed body diameter;
the second fixed body portion comprises a fixed body interior space;
the second contact surface is provided within the fixed body interior space; and
at least a portion of the second spring is provided within the fixed body interior space.

14. The electrical connector of claim **11**, wherein the fixed body further comprises:
a plate; and
a hollow cylinder extending from the plate along the longitudinal axis and defining a fixed body interior space, wherein
the first contact surface is provided on a first side of the plate opposite the hollow cylinder,
the second contact surface is on a second side of the plate opposite the first side and disposed within the fixed body interior space, and
at least a portion of the second spring is provided within the fixed body interior space.

15. The electrical connector of claim **11**, further comprising:
a hollow cylindrical spacer extending along the longitudinal axis and abutting the second contact surface,
wherein at least a portion of the second spring is provided within an interior space of the hollow cylindrical spacer.

16. The electrical connector of claim **11**, further comprising:
a retainer provided in the bore at the second end of the connector body,
wherein the second electrical contact extends through the retainer.

17. The electrical connector of claim **11**, further comprising:
a groove formed on an inner surface of the bore at a position along the longitudinal axis between the second contact surface and the second aperture;
a retainer ring provided within the groove;

a washer provided between the retainer ring and the conductive fixed body, the washer abutting the retainer ring; and

a hollow cylindrical spacer positioned between the washer and the conductive fixed body, wherein

the second electrical contact extends through the retainer ring and the washer,

at least a portion of the second electrical contact is provided within an interior of the hollow cylindrical spacer, and

the second spring is provided within the interior of the hollow cylindrical spacer.

18. The electrical connector of claim **17**, wherein the hollow cylindrical spacer is monolithically formed with the conductive fixed body.

19. The electrical connector of claim **17**, wherein the hollow cylindrical spacer is monolithically formed with the washer.

20. An electrical connector comprising:

a connector body extending along a longitudinal axis;

a first electrical contact provided at a first end of the connector body;

a first aperture provided in the first end of the connector body;

a bore provided in an interior of the connector body, the bore being connected to the first aperture;

a conductive fixed body provided within the bore, the conductive fixed body comprising a first contact surface on a first side of the conductive fixed body facing the first electrical contact along the longitudinal axis; and

a first spring provided in the bore between the first contact surface and the first electrical contact, the first spring being in contact with the first contact surface and the first electrical contact,

wherein the bore comprises:

a first bore portion having a first bore diameter;

a second bore portion axially adjacent to the first bore portion and having a second bore diameter larger than the first bore diameter;

the connector body further comprises an annular shoulder formed at a transition between the first bore portion and the second bore portion;

the first contact surface abuts the annular shoulder; and

the first spring and at least a portion of the first electrical contact are disposed within the first bore portion.

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